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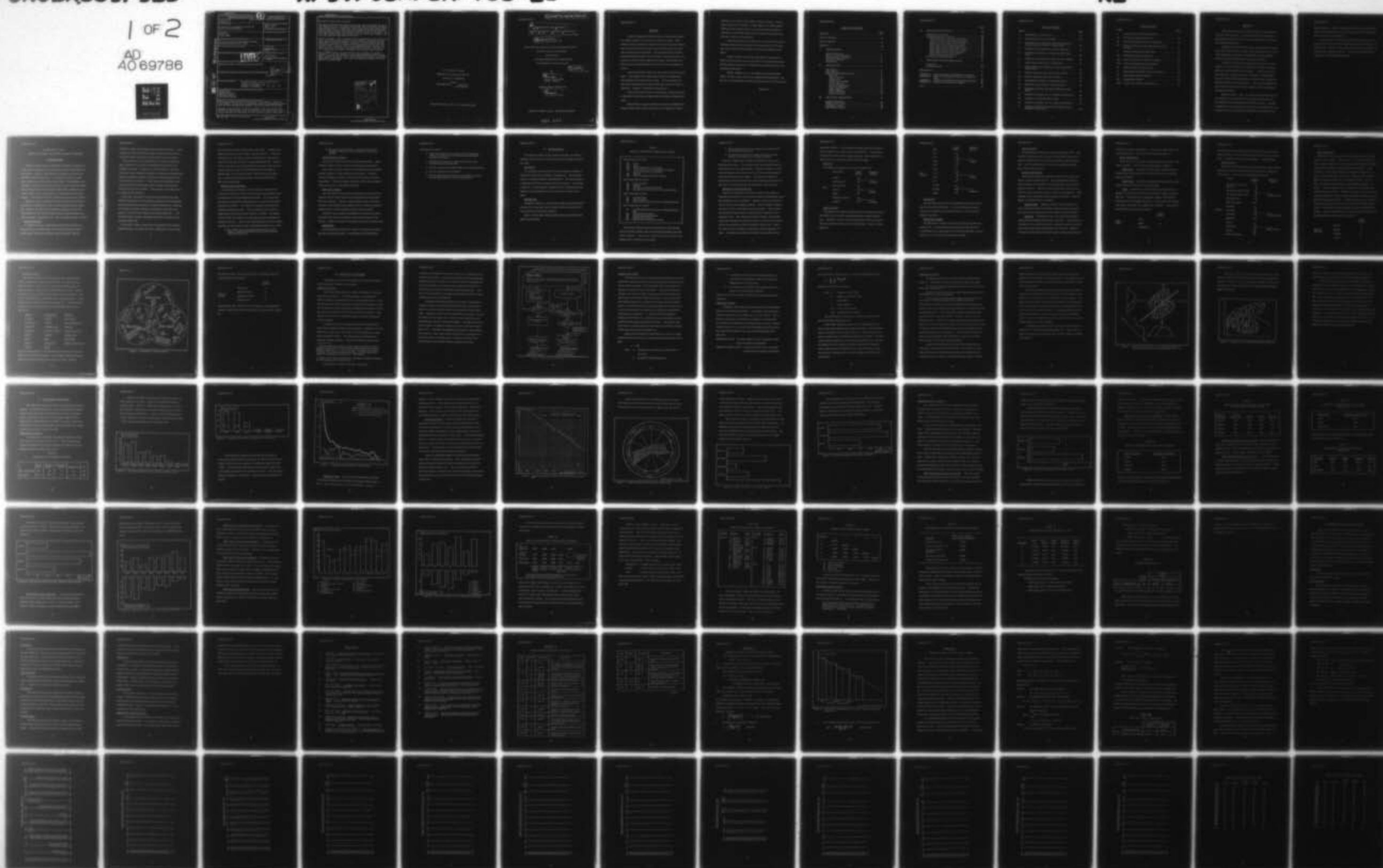

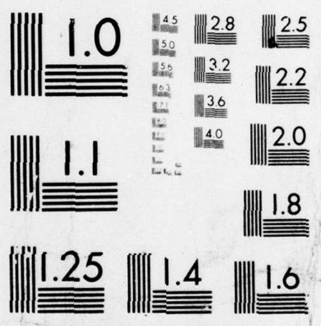

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This study examined the data about accidents in the Republic of Korea Air Force (ROKAF). The purpose is to help decide where to put management emphasis with the aim of decreasing the accident rate and increasing flying safety.

Variables associated with 312 aircraft accidents which occurred from 1955 through 1977 were defined, coded, and analyzed to see if there were relationships among these variables which can help illuminate ROKAF accident rates

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and fatality rates given an accident.

Accident rate analysis and learning curve theory were used to study the accident potentiality while contingency analysis was used to determine the dependence between variables. Among them, aircraft type, pilot rank, mission type, phase of operations, and flying time were selected for discriminant analysis, which was done to explain the fatalities of pilots involved in accidents. The first four variables were each ordered by level of risk of each category, and the fifth indicates proficiency of the pilot.

Results are these: first, two-thirds of the accidents were due to the pilot's error, and the pilot error accident rates decreased as the cumulative time experienced by the ROKAF increased. Secondly, in-flight phase was the most likely to be involved in accidents and, when accidents did occur, the pilot was most likely to lose his life if in the approach process. Thirdly, variables which had a significant relationship with pilot injury level were aircraft type, pilot rank, phase of operation, mission type, and flying time.

study
Based on those results, the most effective way to decrease the accident potential is to pay more attention to pilot error accidents in the in-flight phase. However to save the pilots' lives involved in accidents, the approach phase should be emphasized. This study also includes many tables which are helpful for further study.

AN ANALYSIS OF THE

REPUBLIC OF KOREA AIR FORCE'S

AIRCRAFT ACCIDENTS

THESIS

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Suh Ho Sun
Lt Col ROKAF

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PREFACE

From the beginning of flight until today's modernized aerospace era, flying accidents have occurred too numerous to count. Many studies have been conducted to determine the cause of aircraft accidents and to recommend corrective actions that will either reduce or, hopefully, eliminate aircraft accidents. This study analyzes the possible relationship among a number of the important variables associated with accidents in order to better understand accidents, which perhaps will lead to actions to reduce accidents and thus save lives and material resources.

As with most efforts of this type, this study is truly not my work alone. I am indebted to the many people who have contributed their time and effort to the success of this study. The list of people who have helped and encouraged me during this study is much too long to include here. However, I would like to mention a few.

First of all I wish to thank my thesis advisor, Professor Edward J. Dunne for his many hours of patient help and guidance throughout this study.

Special thanks are given to Professor Charles W. McNichols for being my thesis reader and for showing me how to apply data analysis

techniques to my concern about ROKAF aircraft accidents. Appreciation is given also to Professor T. Roger Manley, my faculty advisor. Without his deep consideration for my special educational program I know that my AFIT study could never have matured to the point where this paper could have been produced.

I also wish to thank Mr. Keon Ho Cho, researcher of the Science Exchange Program between the United States and Korea, for his assistance in the computer programming necessary for the analysis in this thesis.

I want to express my sincerest appreciation to Miss Katie M. Wells who has sacrificed her time and talent in a most unselfish manner. She has helped me overcome my difficult writing problems and has done the typing of this thesis.

Finally, needless to say, I am thankful to my unaccompanied family - my wife, Chung, and two sons, Seung Bum and Seung Chan - for their love, encouragement, and endless patience during my AFIT program.

Suh Ho Sun

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ABSTRACT

This study examined the data about accidents in the Republic of Korea Air Force (ROKAF). The purpose is to help decide where to put management emphasis with the aim of decreasing the accident rate and increasing flying safety.

Variables associated with 312 aircraft accidents which occurred from 1955 through 1977 were defined, coded, and analyzed to see if there were relationships among these variables which can help illuminate ROKAF accident rates and fatality rates given an accident.

Accident rate analysis and learning curve theory were used to study the accident potentiality while contingency analysis was used to determine the dependence between variables. Among them, aircraft type, pilot rank, mission type, phase of operations, and flying time were selected for discriminant analysis, which was done to explain the fatalities of pilots involved in accidents. The first four variables were each ordered by level of risk of each category, and the fifth indicates proficiency of the pilot.

Results are these: first, two-thirds of the accidents were due to the pilot's error, and the pilot error accident rates decreased as the cumulative time experienced by the ROKAF increased. Secondly, in-flight phase was the most likely to be involved in accidents and, when accidents did occur, the pilot was most likely to lose his life if in the

approach process. Thirdly, variables which had a significant relationship with pilot injury level were aircraft type, pilot rank, mission type, phase of operation, and flying time.

Based on those results, the most effective way to decrease the accident potential is to pay more attention to pilot error accidents in the inflight phase. However, to save pilots' lives involved in accidents, the approach phase should be employed. This study also includes many tables which are helpful for further study.

AN ANALYSIS OF THE REPUBLIC OF KOREA AIR FORCES' AIRCRAFT ACCIDENTS

I. INTRODUCTION

In light of its short history, the ROKAF has achieved a rapid development, due to help from the U.S. government and the untiring efforts of its members. However, North Korea has increased its air power continuously since the Korean War. As a result, it now has two times more aircraft then the ROKAF has (Ref 17:102). This development has led ROKAF leaders to the conclusion that the only way to keep the ROKAF strong enough to be able to successfully engage enemy airpower is to get more advanced air force systems and/or to improve the ROKAF pilots' training. The scarcity of economic resources makes the former unlikely.

Therefore, these circumstances make it mandatory that the ROKAF concentrate on training better pilots to improve National defence capability. However, the decision to change pilots' training in the past has brought about the loss of ROKAF pilots' lives and other incidental costs, such as aircraft, compensation, etc. Thus, an accident analysis is needed.

Review of Research

It is difficult to read a journal dealing with ROKAF accidents and find at least one article pertaining to the analysis of accidents; the exception being "The Survey of ROKAF Aircraft Accidents" (Ref 18).

The ROKAF Safety Board had done a basic analysis of the data. Their analysis was sufficient for their purpose, but the aim of this study is to examine closely and analyze in depth ROKAF aircraft accidents.

On the other hand, many reports on U.S. aircraft accidents were found, which were a great help in establishing the hypotheses to be verified in this study. Among them, USAF Capt Paul A. Lantz had shown how various categories compared on a category-by-category basis through a contingency analysis in the study "Study and Analysis of Air Force Helicopter Accidents". In that report the relationships among aircraft type and accident classification, or phase of operation and cause of accident, were verified. This is similar to the method used to analyze ROKAF accidents.

In the study "Reasons for Certain Errors in Piloting" (Ref 19:2), Dimitrov found that the "most important conditions for preventing flight accidents arising from pilot errors in piloting technology are improving the methods of training, education, and discipline of the flight crew, seeing to it that pilots have sufficient accumulated flight time." This study illustrated a possible relationship between the accident rate and cumulative flight time.

In the report "Causes, Survival Rate and Incidence of Poor Weather Affecting Distress Air Cases" (Ref 20:4), Milligan gave a way to define

the "severity of accident" that was used in this study. "Accident rate", which is the focal point of our study, was also studied in: "Statistical Analysis of U.S. Navy Major Aircraft Accident Rates, Pilot and Aircraft Time-Dependent Variables" by Abdur Rashid (Ref 21); "Analysis of U.S. Navy Major Aircraft Accident Rates by Aircraft Type" by Gary Fredric Johnson (Ref 22); "Factors Involved in the Variability of Monthly Major Aircraft Accident Rates" (Ref 23) by Gray K. Poock; and "A Risk and Comparative Analysis of Aircraft Accident Rate" (Ref 24) by James Burlin.

Statement of the Hypotheses

For analyzing the accidents, the most important thing is first to measure the accidents, and the next is to find out which variables seem to demonstrate some relationship with accidents. We can represent the number of accidents by a quantitative unit, but this does not wholly describe the accidents. The severity of accidents can and should be measured in qualitative units. Thus, two scales can be used for in-depth analysis and representation of ROKAF accidents: one dealing with the number of accidents; the other with the types of accidents resulting in pilot death. Based on the knowledge gained from those reports introduced in the previous section, the following hypotheses were made:

1) The accident rate, representing the occurrence of accidents, is decreasing according to the increase of ROKAF cumulative flying time.

2) The severity of the accident, as determined by several variables, explains the fatality of pilots involved in the accident.

Formal Problem Statement

This study is conducted to answer the following question: Where should the emphasis be put to increase flying safety in the ROKAF?

Safety policy in the past appears to be based primarily on intuition; perhaps, because of a lack of ability in data analysis. Decisions arrived at through an analysis of the data are more likely to increase flying safety. This study contains an analysis of data to test variables which seem to have a relationship with safety.

Scope and Limitation

Due to the limited amount of data available and the time constraint imposed, only the major accidents occurring during the period 1955 to 1977 were examined. However, minor accidents could, with further research, prove helpful in determining the rate of accident occurrence and the amount of injury to pilots involved in minor accidents.

In addition, these results are applicable to the ROKAF only under the premise that there is no dramatic change in the structure of the ROKAF. Chapter II provides a thorough description of the subject data.

Assumptions

It is assumed that the ROKAF is anxious to minimize the accident rate and increase flying safety. In analyzing the data the following

assumptions were made:

1. That a linear regression or whatever other relationship results is assumed to correctly portray the relationship between the variables.

2. That the data is of interval (parametric) quality within the limits of approximation used.

3. That the measurement variation follows a normal distribution.

4. That the variations occur randomly.

5. That the independent variables are not mutually correlated to some other variables (no multi-collinearity).

II. METHODOLOGY

This Chapter contains the data selection procedure, the methods employed in data preparation, and the definition of variables treated in this study.

Data Source

It is mandatory that all ROKAF aircraft accidents be reported in detail to the Safety Board in ROKAF Headquarters. The reporting criteria is detailed in ROKAF Regulation 127-1. The Safety Board is a repository for all data recorded on aircraft accidents. "The Survey of ROKAF Aircraft Accidents", published by that organization and the members of that organization, are the sources of data used in this study.

Data Selection

As stated in Chapter I, the goal of this study is to analyze ROKAF accident data to determine which variables tend to be associated with the occurrence and severity of accidents.

Table I lists the data initially requested from and provided by the ROKAF Safety Board.

TABLE I

DATA SET REQUESTED FROM SAFETY BOARD

Data Concerning the Pilot

(1) Rank
(2) Name
(3) Total Flying Time (if available)
(4) Total Flying Time in Aircraft Model in Which Accident Occurred (if available)
(5) Injuries
(6) Class Standing During Pilot Training

Data Concerning the Aircraft

(1) Type and Model
(2) Damage
(3) The Year It Entered the ROKAF
(4) Identification of the System or Component Failure

Data Concerning the Flight

(1) Assigned Wing
(2) Type of Mission
(3) Phase of Operation in Which the Accident Occurred

Data Concerning the Accident

(1) Accident Identification Number, Including Calendar Date
(2) Other Personnel Injured
(3) Contributing Causal Factors
(4) Weather (if available)
(5) Special Data Not Otherwise Listed

The data set acquired consisted of information on four-hundred-twenty-two (422) accidents which occurred during Calendar Year 1955 to 1977, inclusive. Selection of a suitable time span was based on the following basic constraint considerations.

1. The necessity to have a large sample size to enhance validity of statistical inferences.

2. To restrict the cases in the sample to periods when the situation of operation was reasonably consistent.

From the available data set 10 basic variables were selected for inclusion in this study. To accomplish these major considerations the entire data base was initially included. Then each variable was examined throughout the entire data set in terms of how the inconsistencies in the data would affect that variable. This treatment resulted in eliminating the information about the minor accidents and condensed the data base to be used for the three-hundred-twelve (312) accidents.

Overview and Variable Selection

In general, many analysis techniques require that variables are measured on an interval or a ratio scale and that the relationships among the variables be linear and additive. However, there is no such limitation in the case of contingency analysis. So the contingency analysis is used to look for relationships among the variables. But for regression analysis and discriminant analysis the above assumptions were assumed to hold. After listing each accident variable, each possible value of the variable was coded with a specific code number for convenience of the calculations, either a nominal or metric scale. Some of the values of some variables are regrouped to provide significant results. If categories are defined too narrowly, sparse data prevents

any useful conclusion. But the desired distinction between variables is lost if categories are defined too generally (Ref 4:7). The following section defines each variable category and gives, where applicable, an explanation of the category divisions used in this study.

Pilot Rank

The following coding approach was used for pilot rank.

	Designation	Coded Number	Regrouped Number
Rank	Student	1	1 Unskilled
	2nd Lieutenant	2	
	1st Lieutenant	3	2 Skilled
	Captain	4	
	Major	5	
	Lieutenant Colonel	6	3 Familiar
	Colonel	7	

Type of Aircraft

The original data contained 22 different types and models of aircraft. This number was reduced by categorizing by type or general mission area. Appendix A shows all the aircraft which the ROKAF possesses. These are grouped according to their major function; fighter, trainer, supporter.

	Type	Coded Number	Regrouped Number
	F-4	1	
	F-5	2	
	F-86	3	1 Fighter
	F-51	4	
	T-33	5	
Type Aircraft	T-37	6	
	T-28	7	2 Trainer
	T-6	8	
	C-Type	9	
	H-Type	10	3 Supporter
	Utility	11	

Flying Time

The total flying time of each pilot involved in an accident was also coded in increments of 500 hours. As the total flying time ranged from 1 hour to 4,000 hours, the numbers from 1 to 8 were used for coding that variable.

Flying Time In Model

The flying time in model of each pilot involved in an accident was coded as well. It was categorized in increments of 500 hours also. As the flying time in model ranges from 1 hour to 3,000 hours, the numbers from 1 to 6 were used for coding that variable.

Year of Accident

The original data contained all accidents from 1955 to 1977. This variable is important for the accident rate calculations and for the regression analysis between the accident rate and the cumulative flight time. Since this information was not used in contingency analysis, there was no need to regroup.

Accident Classification

All aircraft accidents are classified as being either a minor accident or a major accident (Ref 1:3). But the acquired data about the minor accidents are not detailed, so minor accidents were exempted from the data base. However, since the information about the occurrence is correct, this data is used in accident rate calculations. Major accidents can be grouped into major damage and destroyed. Both are defined in the ROKAFR 127-1 as follows:

Major Damage. "Damage in which the total manhours to remove, repair and replace the damaged components equals or exceeds the limit set for that particular type and model of aircraft (Ref 1:4)."

Destroyed. "Damage that renders the aircraft of no further value except for possible salvage of parts (Ref 1:4)." Direct manhours is defined as "the cumulative man-hours required to repair the aircraft and to remove and replace the damaged parts" (Ref 1:2). ROKAFR also lists each type of aircraft with the number of direct manhours used

to determine accident classification. In this study, major damage was coded with number 1, and destroyed was coded with number 2.

Injury Classification

In this data base, the number of categories of injury is three: none, minor, and fatal. The criteria of each category is as follows:

Minor Injury. Any injury less than major, but which requires hospitalization and/or quarters for at least one day, but no more than four days (Ref 2:3).

Major Injury. Any injury that requires admission to the hospital and/or quarters for five days or more (Ref 2:3).

Fatal. Any injury that results in death from the accident, regardless of the length of time between the receipt of injuries and death (Ref 2:4). For the purpose of contingency analysis, and to provide enough data for a meaningful comparison, "minor injury" was combined with "none", and "fatal" was combined with "missing". This resulted in the following three distinct categories:

		Coded Number
Injury Class	Fatal	1
	Major	2
	None/Minor	3

For the purpose of discriminant analysis (which attempts to discover which variables are more powerful in predicting the injury of the pilot) these 3 categories were regrouped to 2 groups: nonfatal and fatal.

Type of Mission

The types of missions flown by aircraft vary greatly, and the following thirteen categories were chosen to best represent the majority of mission types. These 13 were regrouped by mission type:

	Subject	Coded Number	Regrouped Number
Mission	Shooting (air to ground, air to air	1	1 Combat Mission
	Intercept by Radar Control	2	
	Air Combat Maneuvering	5	
	Reconnaissance	7	
	Close Air Support	10	
	Acrobatic	3	2 Training Mission
	Navigation	6	
	Formation	9	
	Instrument	11	
	Liaison	4	3 Support Mission
	Test Flight	8	
	Courier	12	
	Search and Rescue	13	

Phase of Operation

Many studies have been conducted to categorize the phase of operation of aircraft accidents. The U.S. Air Force Inspection and Safety Center categorized phases of operation into engines running (not taxiing), taxiing, takeoff, inflight, landing, and go-around (Ref 3:1). USAF Capt Paul L. Lantz categorized phase of operation for helicopter accidents into ground operation, initial climb, inflight-normal, low level flight and simulated emergency, and landing (Ref 4:12). For this study, four phases have been used: takeoff, inflight, approach, and landing. Takeoff is defined as the time from the start of takeoff roll until reaching safety altitude. Inflight is defined from the time of reaching cruise altitude after initial climbing and including all flight maneuvers before leaving assigned altitude. Approach is defined as the time from leaving an assigned altitude until the aircraft is in the landing configuration. This category involves all kinds of instrument approaches for landing. Landing is defined from the time of completion of landing configuration until the completion of the landing roll.

		Coded Number
Phase of Operation	Takeoff	1
	Inflight	2
	Approach	3
	Landing	4

Cause of Accident

The Accident Safety Board in the ROKAF has long been tasked with the difficult job of determining the single, most important cause of each accident. Often, there are several interrelated causes, or there may not be enough evidence to even determine a cause. ROKAF recognizes only four possible major causes of aircraft accidents: pilot error, material failure, maintenance error, and undetermined. These cause factors are further divided into 23 subfactors. The following list of all the cause subfactors will provide an understanding of what the factors are:

Aircrew	Environment	Aircraft
training	weather	known faults
qualification	terrain	system degradation
capability	navigation aids	fuel load
experience	terminal facilities	change compliance
attitude	mission	configuration
health	light	weapon load
anxiety	temperature	quality of maintenance
fatigue	traffic	

As can be seen in Figure 1, aircraft accidents can occur due to any one cause or any combination of causes. So it would be valuable to discover some relationship between the cause variable and other variables.

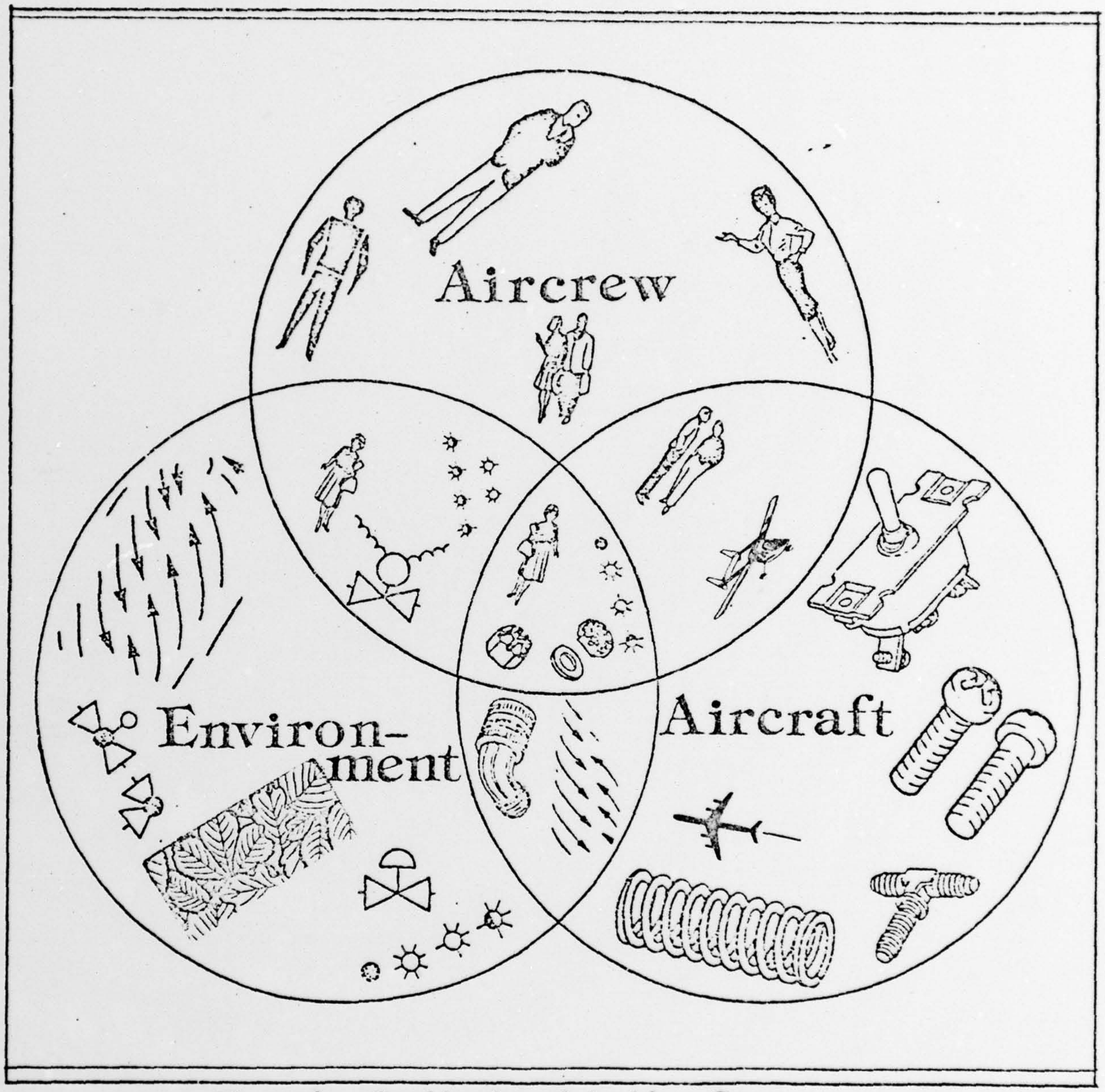

Figure 1. Combination of Accident Cause

The amount of data in each category allowed a reasonable analysis of these four major cause factors.

		Coded Number
Cause of Accident	Pilot Error	1
	Material Failure	2
	Maintenance Error	3
	Undetermined	4

The preceding, then, are all the accident variables, and categories of variables, which were coded for the analysis to be described in Chapter III.

III. ANALYTICAL PROCEDURES

This Chapter contains the description of the analysis procedures and the techniques employed in data analysis.

Analysis Procedures

As an aid in understanding the results of this study, a flow chart is presented in Figure 2. As stated in Chapter II, information on ROKAF accidents was gathered from the "Accident Safety Board". These general reports of ROKAF accidents were treated to an accident rate analysis to discover the general trend and constitution of accidents by aircraft type, phase of operation, type of mission, and cause of accident. Then the data were treated in a contingency analysis to find the dependencies of these variables.

As indicated by F. O. Hemming[1], the accident rate[2] caused by human factor is higher than that of any other factor. Therefore, it is anticipated that in this study as well, pilot error will be found as the major cause of aircraft accidents. This determination is important in the estimation of future accidents. In estimating the future accident rate

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1 "Various authorities in both the United Kingdom and North America suggest that between 55 and 90% of all aircraft accidents can be attributed to human factors." J. M. Rolfe states "that 55% of air transport accidents, 76% of general aviation accidents, and 90% of glider accidents are attributable to human error." (Ref 7:682)

2 Accident rate: Rates are computed on the basis of number of accidents per one hundred thousand flying hours.

Accident Rate = Accidents x 100,000 Flying hours

it would be most important to know the trend and the constitution of accidents by each variable. Learning curve theory can be used (Ref 6:2) in estimating the future accident rate, because it would be reasonable that the rate of accidents caused by pilot error would be decreased by improving the pilot's proficiency through training and experience. After that, it is also important to recognize which variables determine a fatal accident rather than a non-fatal one.

Through the discriminant analysis, the relative contributions of selected variables to the determination of pilot's injury and the discriminant score by which pilots' injuries are classified are studied (Ref 9:69). Quoting the accident rate associated with each category, the nominal values of each category can be converted to the ordinal or metric measurements under this rationale (Ref 10:30). The higher the accident rate, the greater the danger in flying and the more likely is the loss of pilots' lives. If the basic assumptions of this study are valid, policies can be derived, which, when executed by the ROKAF, are likely to decrease the number of accidents and, in so doing, save pilots' lives. The following are the analytical models employed in this study.

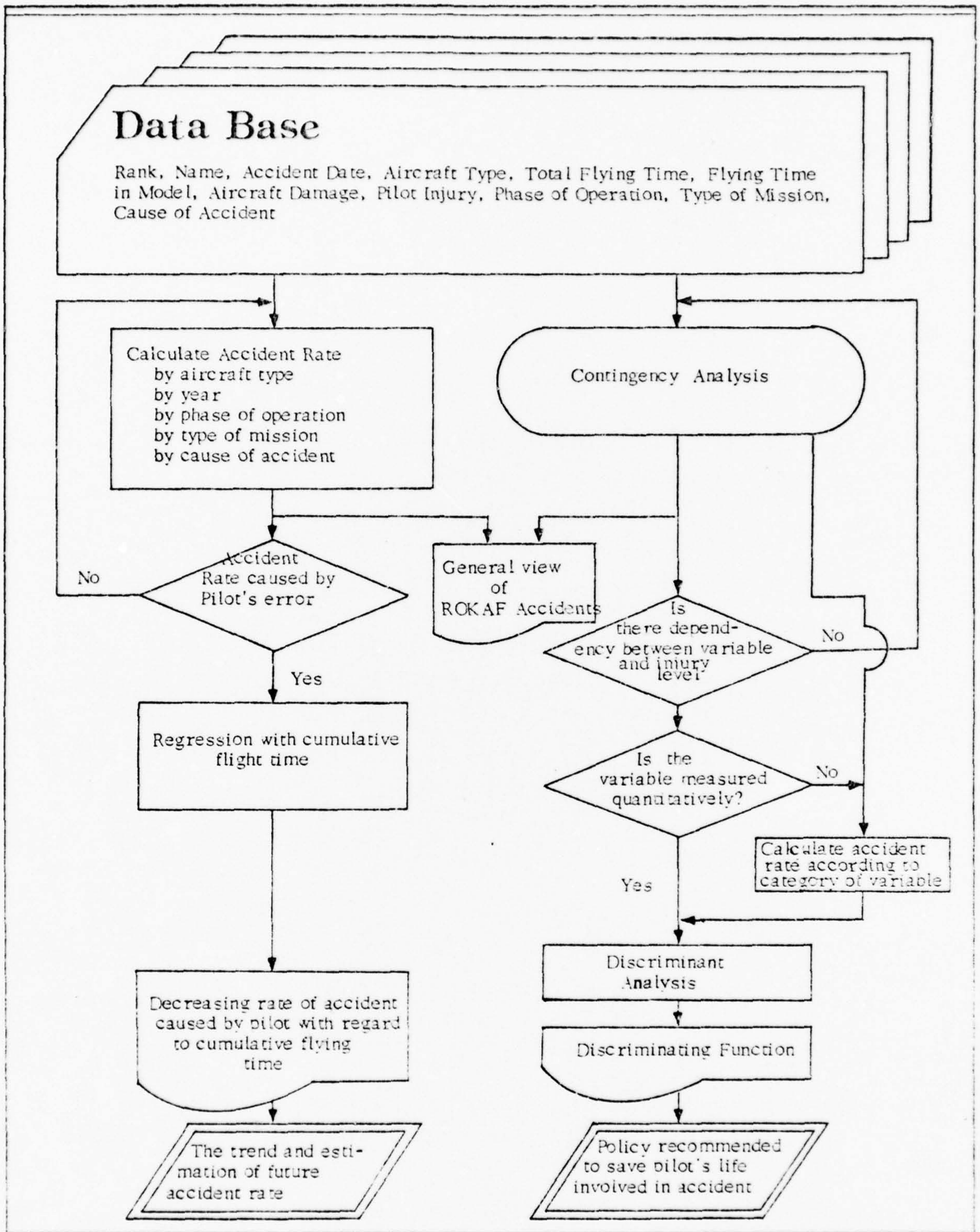

Figure 2. General View of the Flow for Study

Progress Curve Model

This theory reflects the common sense observations that repetitive operations in manufacturing are accompanied by improved efficiency and that the improvement rate is most noticeable early in the program and decreases as quantity increases (Ref 11:6). The most representative example is the division of labor concept depicted by Adam Smith in the 18th Century in the Wealth of Nations (Ref 12:3). If it is assumed that the cumulative flying time is related to the accident rate due to pilot's error in a similar way that the cumulative quantity unit is related to the cost of a unit produced, the progress curve model can be applicable to estimating the accident rate. F. Zeller (Ref 13:179) and John D. Dougherty (Ref 14:197) show a relationship between decreasing accident potential and increasing training and experience. And common sense shows that the training and experience increase the proficiency of pilots, which causes the decrease in accident rate.

Based on the distributions of total flying time and time in model of pilots involved in accidents, the following mathematical model can be built.

$$y = Ax^B$$

where y: the pilot error accident rate by flying time of the x time

x: cumulative ROKAF flying hours

A : a coefficient that represents the theoretical accident rate (also usually expressed number of accidents per 100,000 times) of the first hour

B: a coefficient that is related to the slope and the rate of change of the learning curve (Ref 6:7)

Fitness of that function could be verified by the regression method in Appendix B.

Contingency Analysis

Contingency table analysis may be used to study the relationship between two classification variables. The purpose of the contingency table is to determine if two variables are in any way related. This is done by establishing the null hypothesis that there is no relationship (for example, the variables are independent) between the two variables and then using the x^2 test to see if the null hypothesis should be accepted or rejected in accordance with a pre-selected significance level (Ref 4:18).

Null hypothesis (Ho): The observations are from a population in which the two variables are independent.

Alternative Hypothesis (Ha): The observations are from a population in which the two variables are dependent.

The test statistic, chi-square test, is made by the following equation:

$$x^2 = \sum_{i=1}^{r} \sum_{j=1}^{k} \frac{(f_{ij} - e_{ij})^2}{e_{ij}}$$

with degrees of freedom; (r-1) (k-1)

where r = number of rows in table

k = number of columns in table

i = row number

j = column number

f_{ij} = actual value in cell ij

e_{ij} = expected value for cell ij

The null hypothesis is accepted or rejected in accordance with the predetermined significance level.

In this study, only those tables which were significant at the .1 level or less were considered to be significant enough to make statements about the dependence of the variables involved. Note that this test evaluates the significance of the difference between two variables. The discriminant analysis significance test considers the significance of a variable in conjunction with all variables previously entered into the analysis. Thus, predictor group variable differences could fail to achieve significance using a contingency test, and yet be significant in the discriminant function.

Discriminant Analysis

The following questions can be addressed by the discriminant analysis. The dependent variable is injury level, fatal or non-fatal.

1) Are the two groups significantly different with respect to their multivariate descriptions?

2) What role do the variables for which measurements have been obtained play in separating the group?

3) If responses or levels for the variables are known for a new observation, to which group does the case belong (Ref 9:7-1)?

The procedure constructs a discriminant function based upon input data in which subjects are members of two known groups; fatal pilot group and non-fatal pilot group. This discriminant function is usually linear but can be quadratic or have other forms. The data is used to make the function specific. Typically, it is then used to reassign the original subjects to one of the two groups on the basis of their characteristics in order to make an empirical determination of the rate of misclassification and perfect discrimination between groups. The discriminant function can also be used to categorize other observations, whose group membership is unknown, on the basis of their attributes.

A linear discriminant function will be constructed for the two pilot groups on the basis of fatal or non-fatal. If the function discriminates well, then one can determine what particular variables have the strongest influence on placing a subject in the accident group. Also by

applying the discriminant function to subjects not in the original test groups, one can determine their injury potential. The assumptions upon which discriminant analysis is based and the actual mathematics will be covered in Appendix C.

If the discriminant function fails to separate the groups without a high rate of misclassification (except the case of misselection of variables) the lack of success can be attributed to one of two causes. The first is that the variables characterizing the subjects do not distinguish between the groups to a strong enough degree or the groups overlap too much in the given measurement space. The second is that the groups cannot be separated by a function of the form chosen for the analysis. That is, instead of a linear discriminant function we should have another function (quadratic or more complex).

To illustrate the preceding concept, let the fatal pilot group be denoted by "A" and the non-fatal pilot group by "B". Now, if one considers the groups in two dimensions only, the groups might be clumped as in Figure 3.

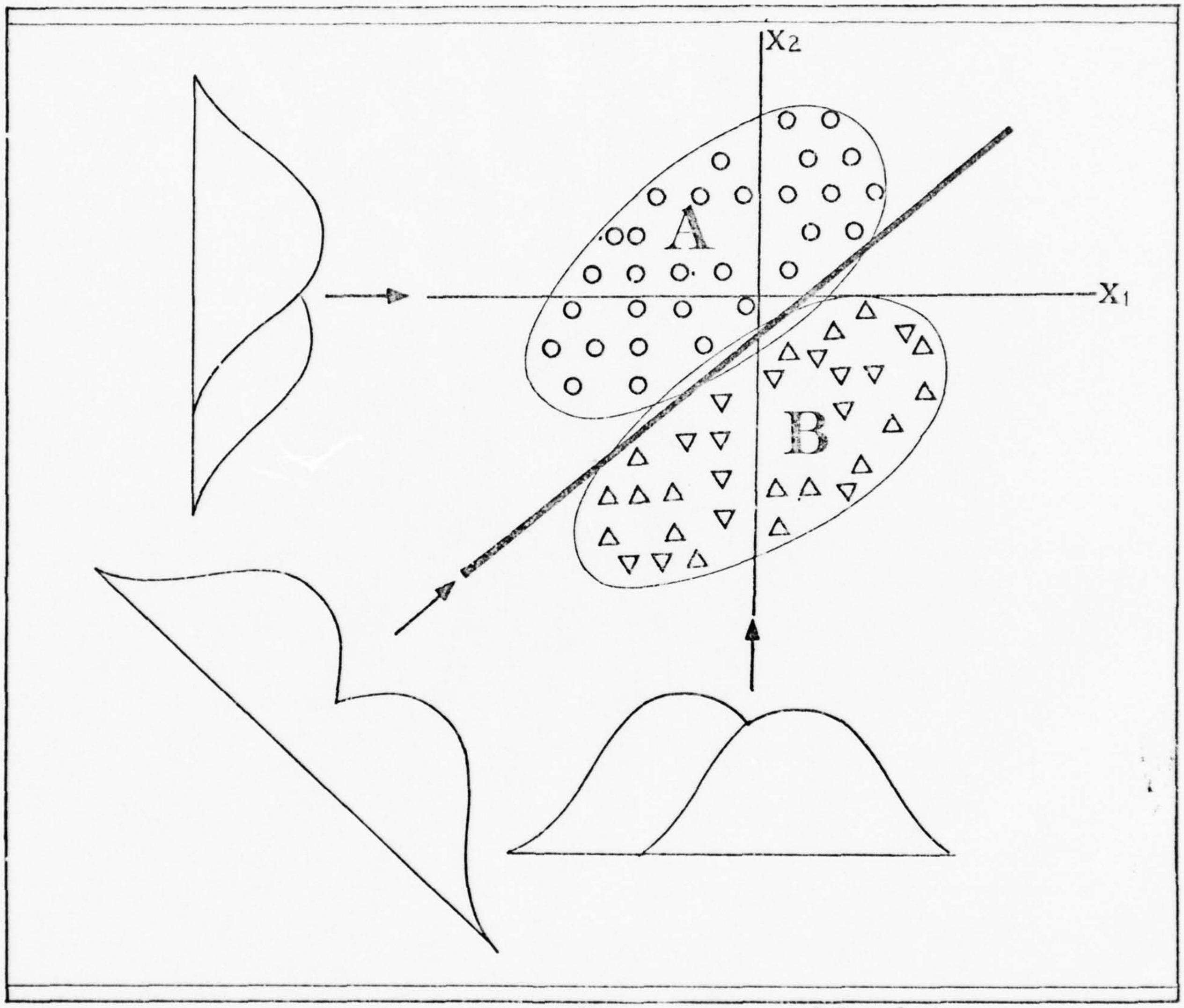

Figure 3. Separation of Two Multivariate Normal Populations as Viewed from Three Different Vantage Points (Ref 9:7-5)

In this case, a linear discriminant function would serve to separate the groups well, and it is not necessary to construct a quadratic function. If, however, the data appeared as in Figure 4, then one can see that a linear discriminant function cannot discriminate among the groups without error.

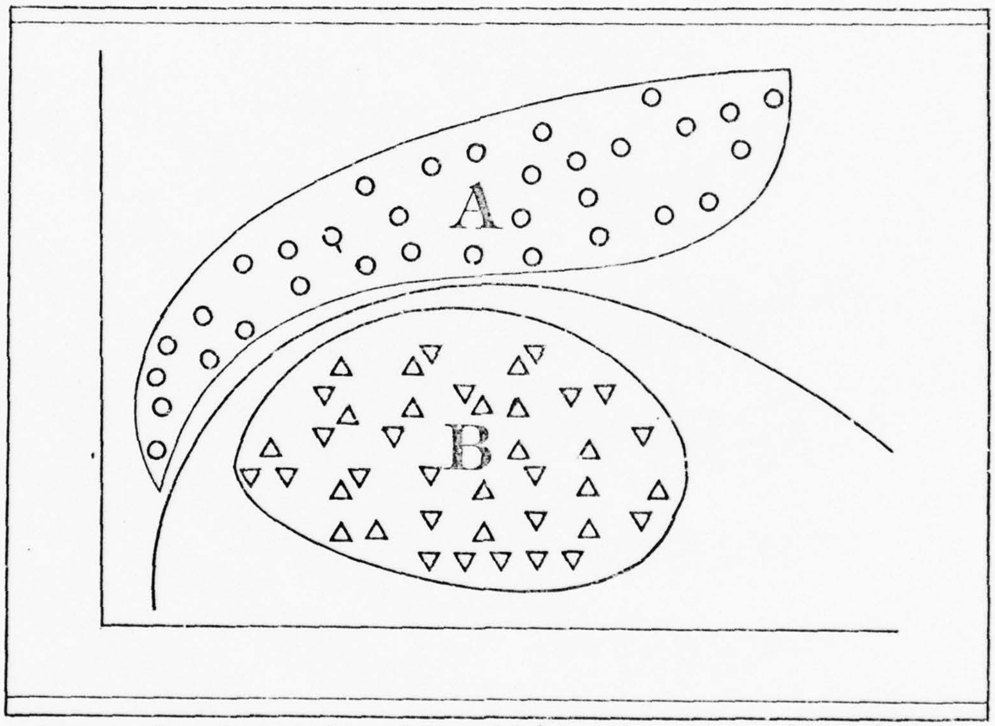

Figure 4. Separation of Two Multivariate Normal Populations

However, a quadratic form of discriminant function such as the curve depicted might very well have excellent discriminating capabilities.

The linear discriminant function is a tool that is immediately available in terms of computer programs. It is based upon the assumption that the data came from a multivariate normal population, and when this assumption is met, it works as well as any other discriminant function. Other discriminant functions are not readily available for use. Also, the linear discriminant function could do a good job even if the multivariate normal assumption is not met; for example, when the natural separation of groups is so great that even a simple method would do the job. For the problem at hand, the use of the linear discriminant function was encouraging, but since the assumption of multivariate normality is not appropriate, it was decided to explore the nature of the data to see if a better method could be employed.

IV. EVALUATION AND RESULTS

This Chapter provides the results and interpretations of the data analysis. It constitutes three parts: first, the distribution of ROKAF accidents and a discussion of the results of the accident rate analysis; second, a discussion of the results of a contingency analysis done to determine the relationship between variables; and finally, a discussion of the results of a discriminant analysis used to determine how variables can affect the severity of injury to the pilot.

Distribution of Accidents

As anticipated in Chapter III, the majority of ROKAF accidents were found to be caused by the pilot's error. Table II shows the distribution of accidents by each cause and implies the importance of analyzing the accidents caused by pilot's error.

TABLE II

PERCENTAGE OF ACCIDENT BY CAUSE

	Pilot's Error	Material Failure	Maintenance Error	Undetermined	Total
No. of Accidents	207	83	8	13	312
Percentage	66.4	26.7	2.7	4.2	100

Figures 5 and 6 show the frequency of accidents by flying time and by flying time in model. Because the correlation coefficients arrived at were -.9567 and -.8576 for these frequencies, it is clear that in ROKAF accidents there is a negative association between number of accidents and flying time. However, this relationship may be simply a reflection of the pattern of flying time among all ROKAF pilots -- those who have had accidents and those who have not.

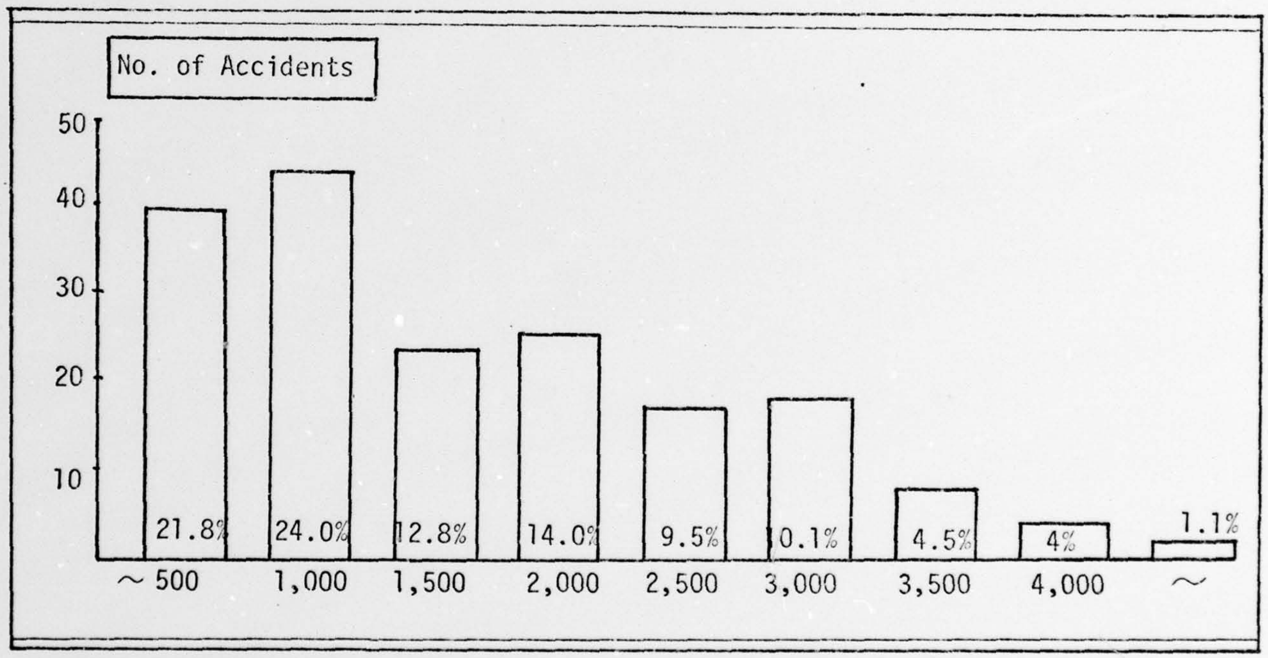

Figure 5. Distribution of Number of Accidents by Total Flying Time

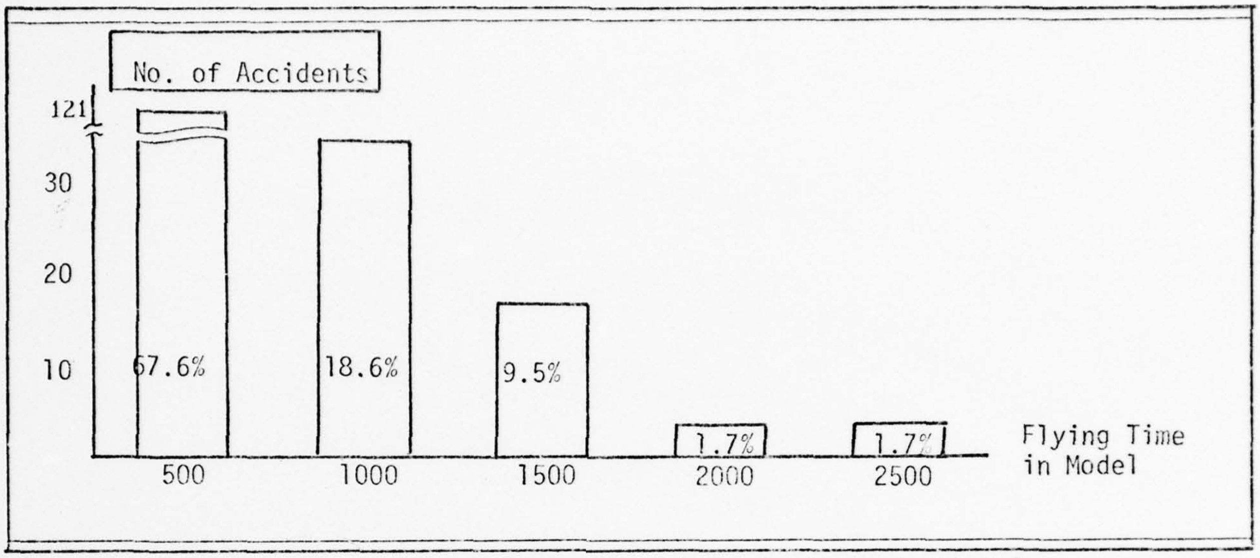

Figure 6. Distribution of Number of Accidents by Time in Model

The following data support the contention that generally the more experienced the ROKAF has become, the lower the accident rate. Figure 7 shows causes for accidents occurring in the period from 1955 to 1977. This chart shows that the rate of accidents due to pilot error is decreasing steeply from 55.0 in 1955 to 0.5 in 1977. That decreasing trend is attributable to two factors: technical factors and managerial factors.

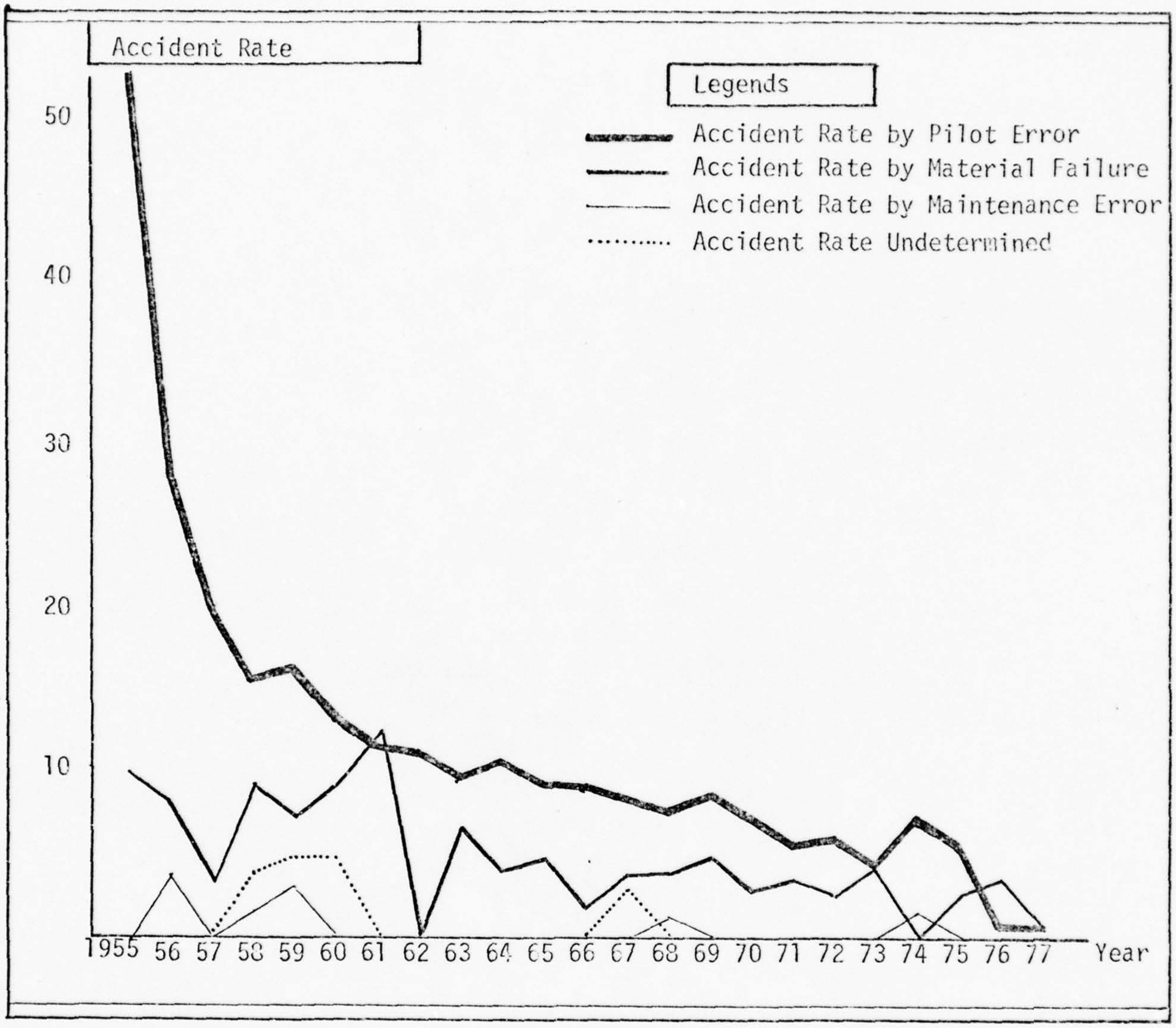

Figure 7. Annual Trend of the ROKAF Accident Rate

Technical Factors. Over these years the ROKAF has gained in experience and increased the quality of the training student pilots receive. This in turn produces more proficient pilots. When the

Republic of Korea instituted its air force there were no manuals for operating aircraft. A few members were trained by the U. S. A. F. during the Korean Conflict. Based on their experience, manuals were prepared. Also, the longer the ROKAF has been in operation, the more flying data and records have been used for better pilot training.

Managerial Factors. Goals for accident rate levels were established by ROKAF leaders based on previously achieved results. This raises the question as to whether the decreasing accident rate is relatively flexible and responsive to their requirements, or is it relatively fixed and thus independent of their control. The issue is debatable. However, it is quite certain that ROKAF policy is to save as many aircraft as possible, for sources of aircraft are strictly limited by the U. S. Government. Historical data were used to determine the relationship between the accident rate and cumulative flying hours.

Figure 8 is included to support the application of the learning curve theory to ROKAF pilot training. It is a regression graph showing the relationship between the cumulative flying time of the ROKAF and the decreasing accident rate. The more experienced ROKAF pilots have become, the greater their collective proficiency with aircraft. This proficiency in turn has resulted over time in a steadily decreasing accident rate.

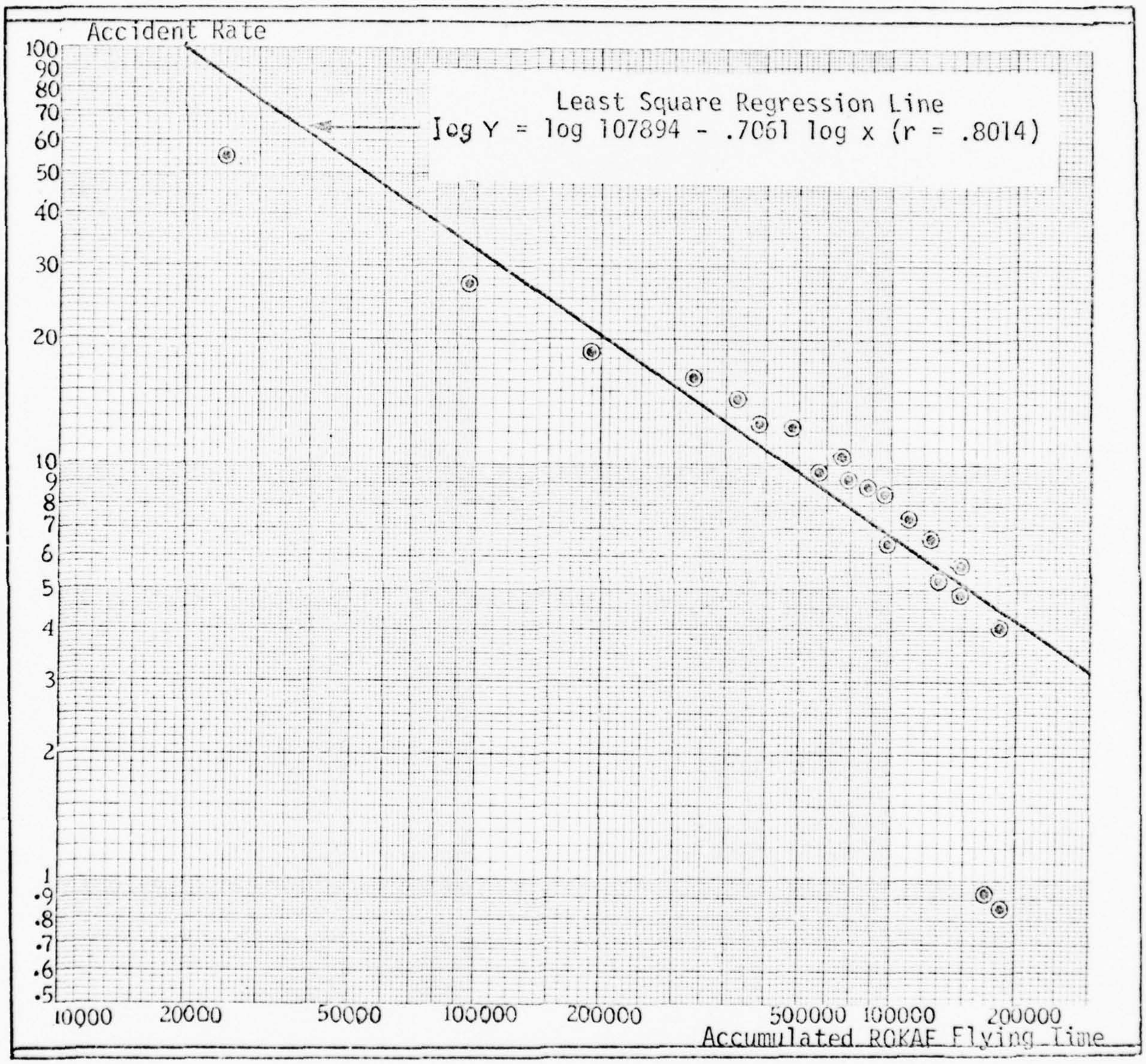

Figure 8. Relationship Between Cumulative Time and Pilot Error Accident Rate

Figure 9 shows accident rates for different types of aircraft. The helicopter has been involved in fewer accidents than any other type of aircraft; cargo type aircraft, trainers, fighters rank after them in

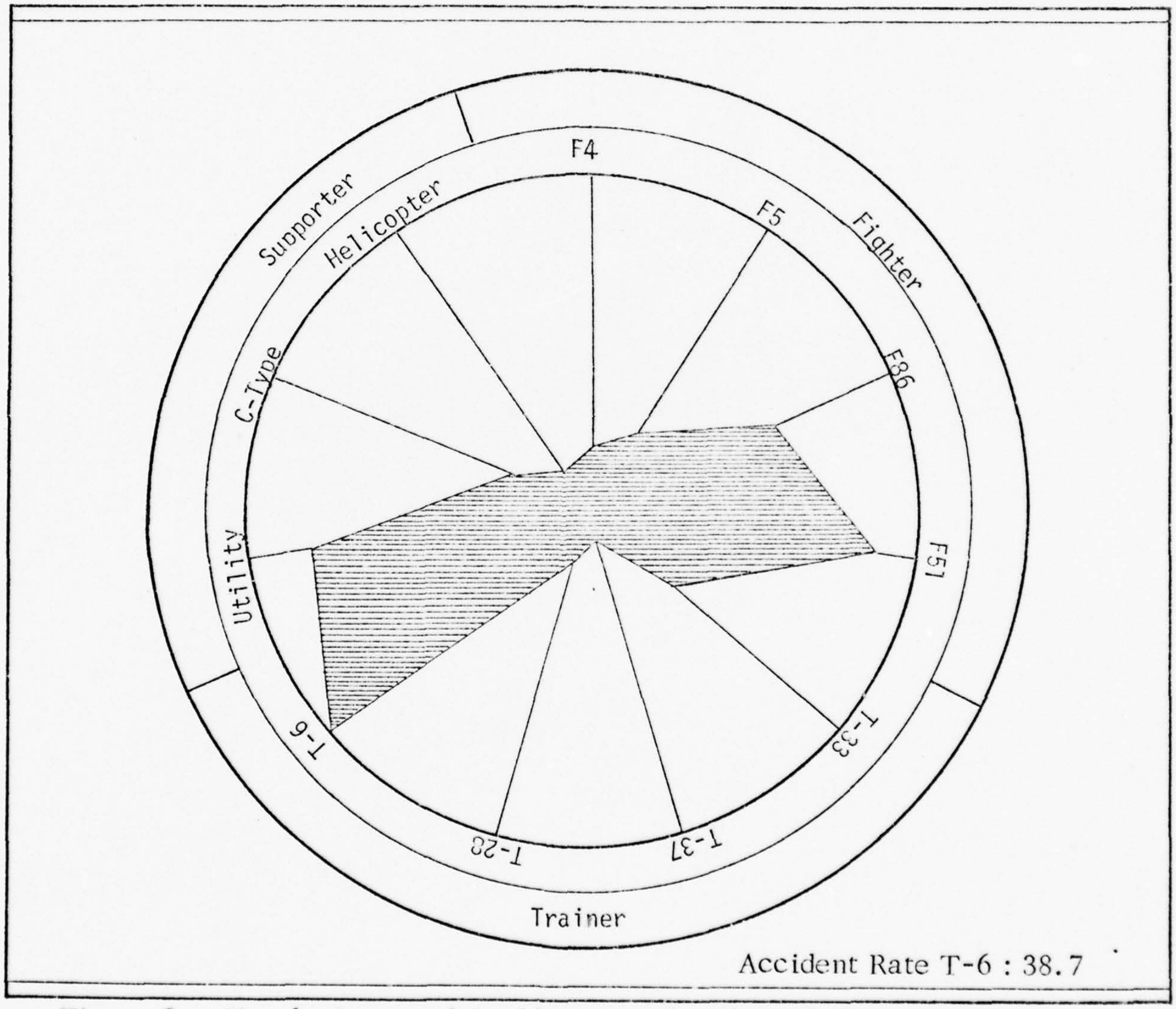

Figure 9. Simple Averaged Accident Rate by Aircraft Type

a descending order of safety. In this case the word safety is not used to describe the nature of the aircraft but rather to reflect the likelihood of an accident occurring to the aircraft. Of the combat airplanes used by the ROKAF, the F-4 is shown as much safer than the F-86. The trainer T-37 is safer than any other training aircraft the ROKAF uses.

With regard to the phase of operation, the in-flight phase is more likely to be involved in accidents than any other phase of operation. The probability of an accident occurring during the inflight phase is four times the probability of one occurring during the approach phase. Figure 10 implies that the order of decreasing accident rate is in-flight, landing, take-off and then, approach.

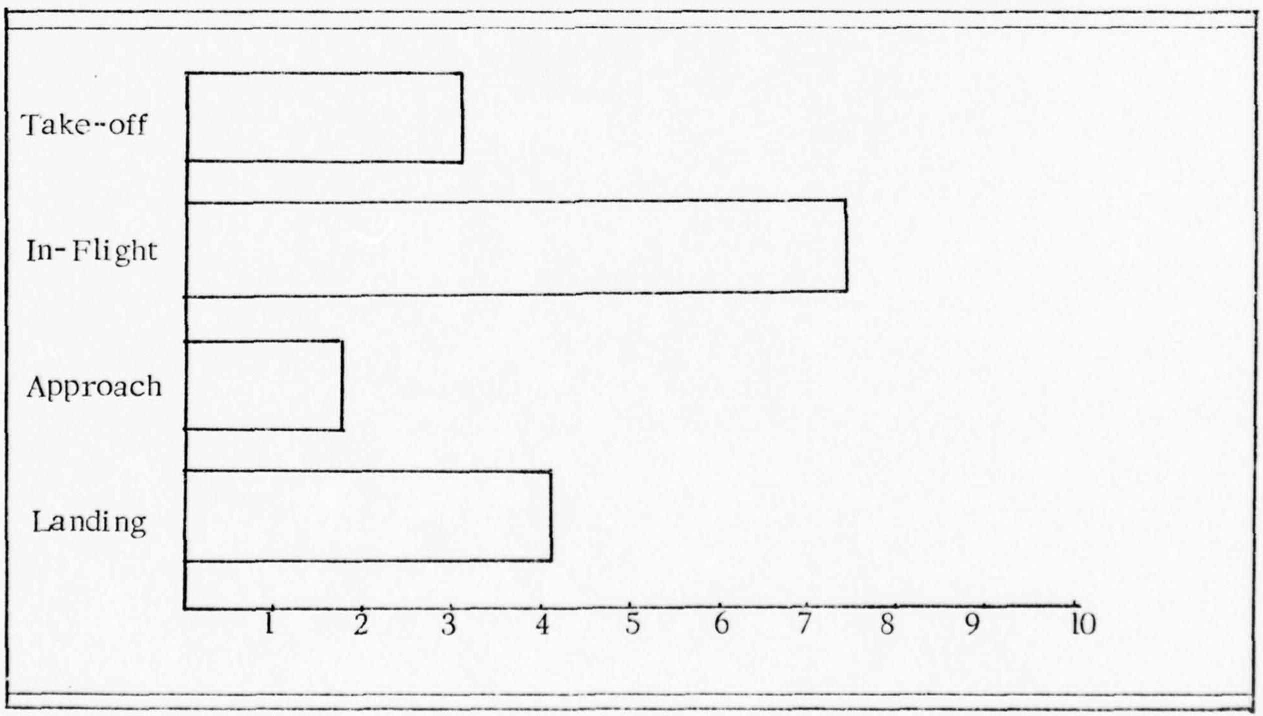

Figure 10. Simple Averaged Accident Rate by Phase

The distribution of accidents by type of mission shows that 44.2% of all accidents occurred during a training mission. The percentage of accidents occurring during a combat mission was 39.7%. Figure 11 shows the distribution of accidents by the type of mission. Support type missions resulted in the least number of accidents.

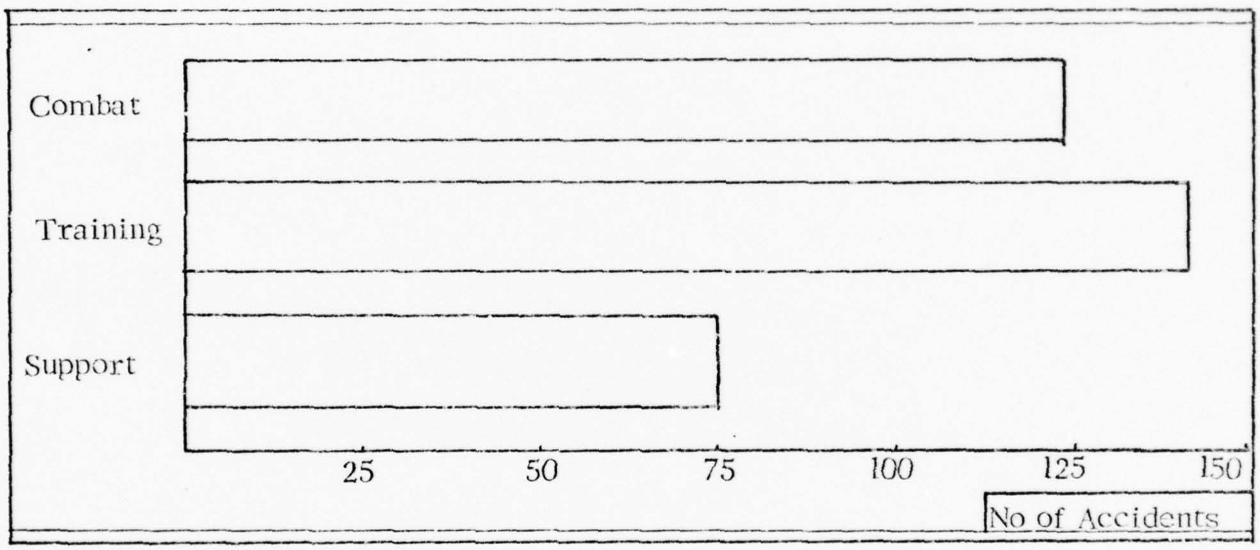

Figure 11. Distribution Number of Accidents by Mission

Relationship Between Variables

It is important to discover any relationship between variables affecting ROKAF accidents as well as to analyze the accident rate in ROKAF, in order to understand the characteristics of ROKAF accidents. This information in turn will help in the prediction and, hopefully, the prevention of further accidents.

In general, the importance of relationships is determined in two ways: through accepting hypotheses and/or rejecting them. When the results of the contingency analysis definitely and statistically confirm conclusions that were hypothesized in the analysis, one has more confidence in accepting the existence of relationships between other, seemingly unrelated, variables which show a high degree of dependency.

When the data indicates no relationship between specific variables, that is useful in dispelling misconceptions about relationships thought to exist. With the hope of finding the variables important in a discriminant analysis, all the variables related to pilot's injury were analyzed. In order to simplify the presentation of results, certain variables thought to be important to pilots' safety, have been selected as the prime variables.

Type of Aircraft Versus Aircraft Damage. The prime variable of aircraft type showed interesting relationships to the other variables. The contingency table of aircraft type versus aircraft damage produced a

significance level of .0002, suggesting that damage was related in a large degree to the type of aircraft involved.

Most interesting was the distribution of destructive accidents over major accidents for a particular aircraft type. Over all there were 94 major accidents and 218 destructive accidents; this yields a destructive/major ratio of 2.31. Figure 12 is the comparison of a destructive/major ratio for types of aircraft. The total number of accidents incurred by each type is found within the bar representing that type.

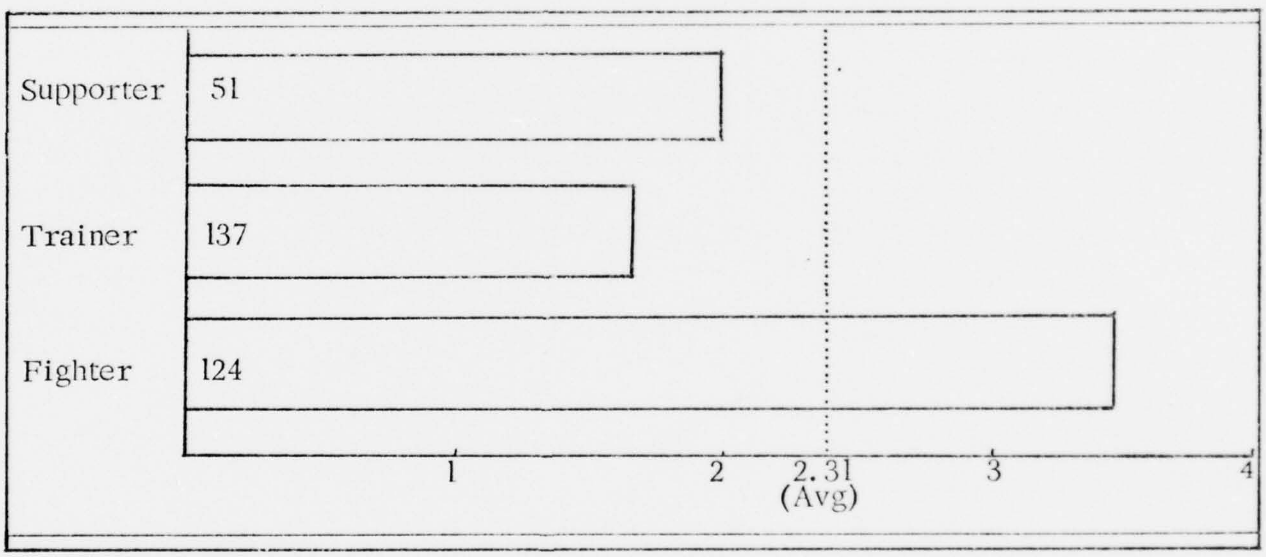

Figure 12. Destructive/Major Ratio by Aircraft Function

Fighters stand out as being two times more likely to be involved in destructive accidents than training aircraft, given the same number of

accidents. Support , then trainer aircraft follow in the order of severity of accidents. Given that an accident occurred, for the whole of ROKAF aircraft the chance of it being a destructive accident was 69.6% (# of destructive accidents x 100/total # of accidents).

Type of Aircraft Versus Phase of Operation. When aircraft type was compared with the aircraft's phase of operation at the time of the accident, the resulting contingency table yielded a significance level of .0007. This indicates that there's a strong relationship between the two variables. For all aircraft the distribution of accidents by phase of operation is shown in Table III.

TABLE III

ACCIDENT DISTRIBUTION BY PHASE OF OPERATION

Phase of Operation	Percentage of Accidents
Takeoff	19.3
Inflight	45.7
Approach	10.6
Landing	24.4

There was some variation in the way the accident phases were distributed for each individual aircraft type as illustrated in Table IV.

TABLE IV

PHASE OF OPERATION ACCIDENT DISTRIBUTION
BY TYPE AIRCRAFT (PERCENTAGE)

Phase of Operation	Overall Distribution	Fighter	Trainer	Supporter
Takeoff	19.3	15.4	20.3	30.9
Inflight	45.7	53.8	39.2	27.3
Approach	10.6	13.2	9.5	3.6
Landing	24.4	17.6	31.0	38.2

Type of Aircraft Versus Type of Mission. Because different aircraft were designed for different missions, one would expect, and the statistics verify, a direct relationship between the type of mission and the type of aircraft. The data yields a significance level of .0000.

Pilot's Injury Versus Phase of Operation. A level of significance of .0000 shows that there is a strong relationship between the pilot's injury and the phase of operation in which the accident occurred. For all phases of operation the distribution of accidents by the degree of pilot's injury looks like this (Table V):

TABLE V

ACCIDENT DISTRIBUTION BY PILOT'S INJURY
(Percentage)

Pilot's Injury	Percentage of All Accidents
Fatal	40.1
Major	15.0
None/Minor	44.9

However, there is much difference within the distribution of each phase of operation as is shown in Table VI.

TABLE VI

PILOT INJURY BY PHASE OF OPERATION
(Percentage)

Pilot Injury	Takeoff	Inflight	Approach	Landing
Fatal	26.7	51.7	60.6	19.7
Major	12.3	13.3	8.1	11.7
None/Minor	55.0	35.0	33.3	60.6

More fatalities were the result of accidents that occurred during the approach phase of a flight. That is to say, of all the accidents occurring during the approach phase, 60.6% resulted in the pilot's death (see Figure 13).

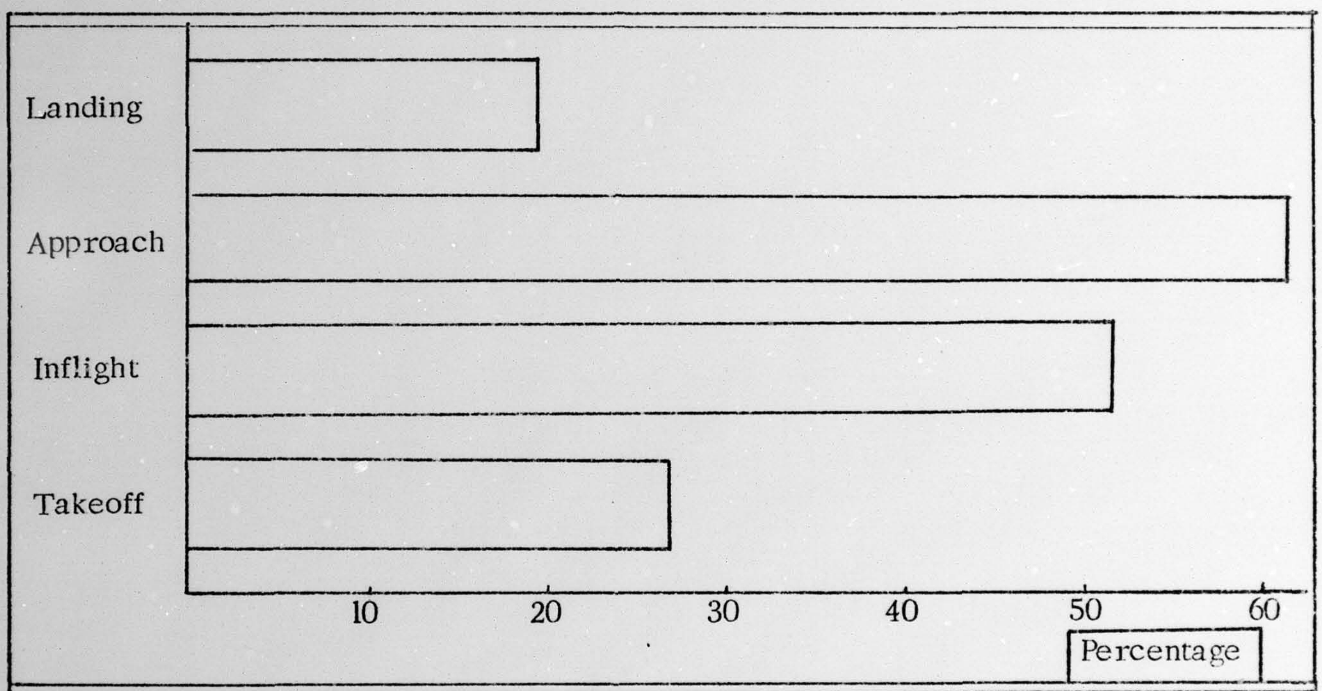

Figure 13. Percentage of Death Occurring in Different Accident Phases

Pilot's Injury Versus Flying Time. There is a relationship between the severity of a pilot's injury and his accumulated flying time. The data yields a significance of .0509. It may be noted that, of all ROKAF accidents, although more occur in which pilots have 2000 or

less flying hours than 2000 to 4000 (which may be because the ROKAF has more pilots with 2000 or less flying hours), there is a greater percentage of fatalities for accidents involving pilots with 2000-4000 flying hours.

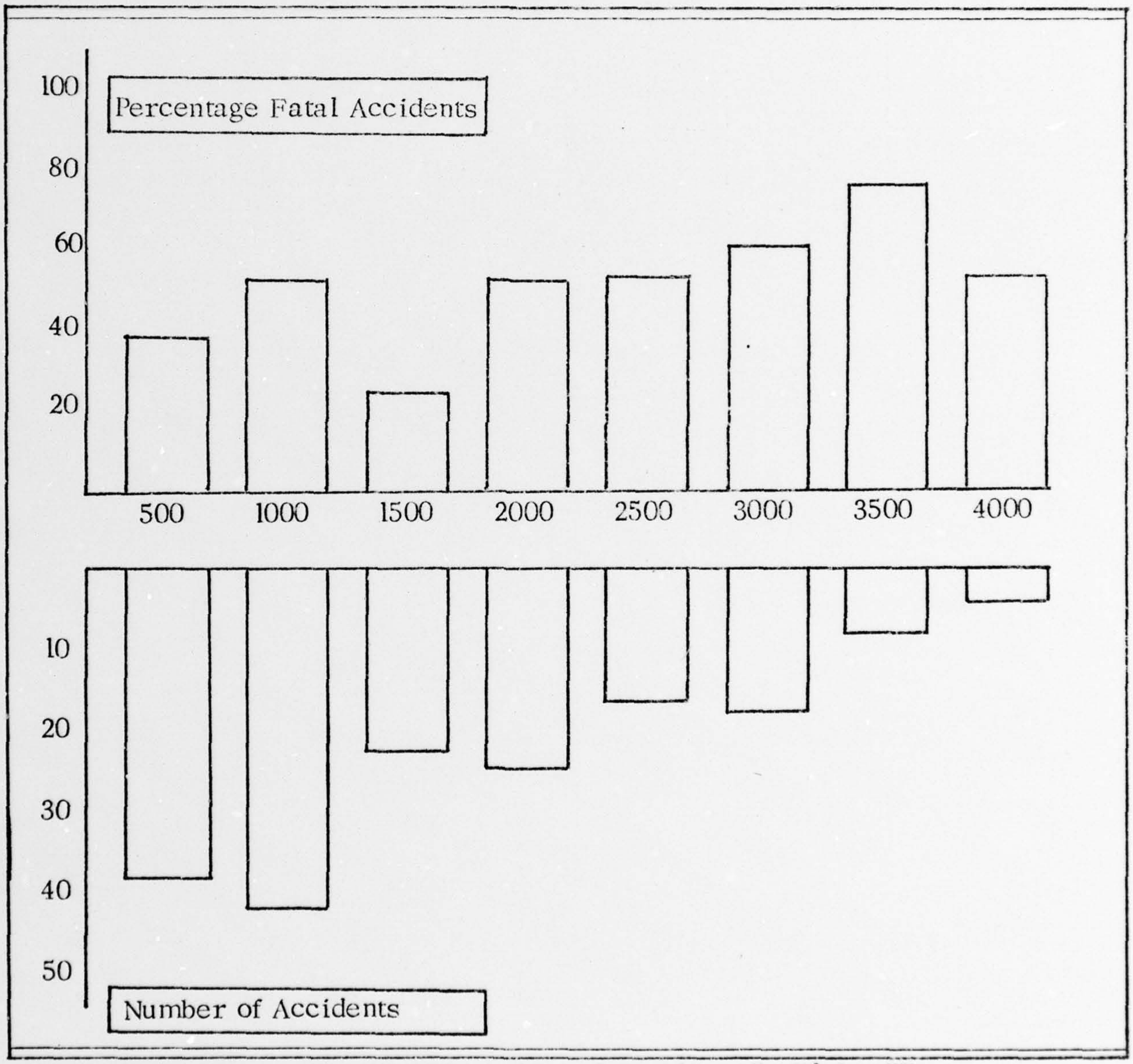

Figure 14. Severity of Accident, No. of Accidents By Flying Time

<u>Pilot's Injury Versus Flying Time in Model</u>. Even though there is a relationship between the severity of the pilot's injury and total flying time, there is no relationship between pilot injury and the flying time in model. Analysis showed a .6838 level of significance.

<u>Pilot's Injury Versus Cause of Accident</u>. A contingency analysis between the degree of pilot injury and the cause of the accident yielded a significance level of .8922. Therefore, it is concluded there is no relationship between the variables.

<u>Pilot's Injury Versus Type of Mission</u>. The degree of pilot injury shows a slight relationship to the type of mission. The contingency yielded a level of significance of .0646. If we take a look at the mission type, close air support accidents have the highest percentage of fatalities, and then instrument flight, shooting, aerobatic, and formation follow in the ranking of types of accidents yielding fatalities. As expected, combat mission accidents resulted in a high number of pilot fatalities (Ref: Figure 15).

<u>Pilot Injury Versus Pilot Rank</u>. Pilot rank was found to be statistically significant in determining the degree of pilot injury (.0651). Figure 16 suggests that a Major is more likely to die when involved in an accident.

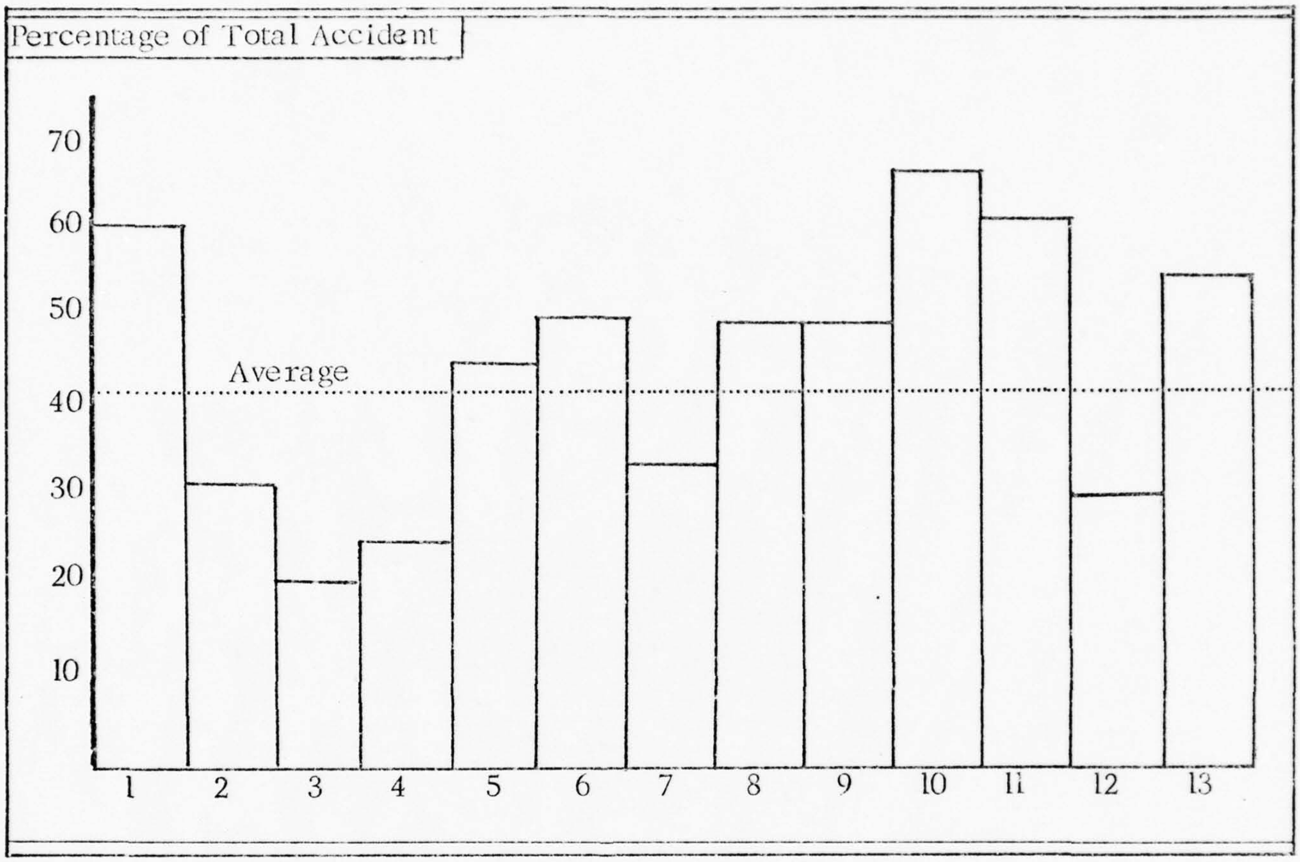

Figure 15. Severity of Accident by Type Mission

1. Shooting
2. Intercept by Radar Control
3. Acrobatic
4. Liaison
5. Air Combat Maneuvering
6. Navigation
7. Reconnaissance
8. Test Flight
9. Formation
10. Close Air Support
11. Instrument
12. Courier
13. Search and Rescue

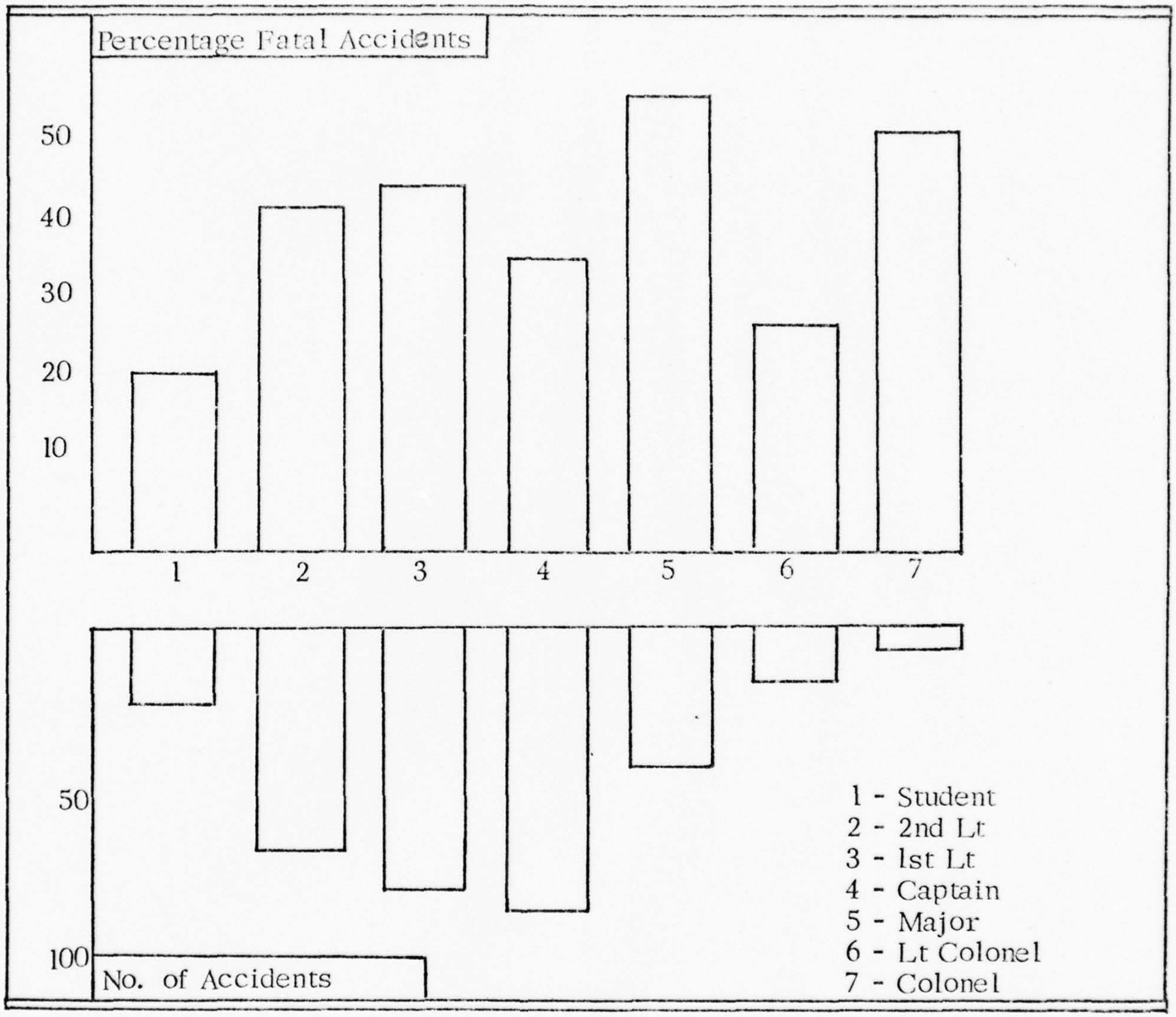

Figure 16. Severity of Accident, No. of Accidents by Pilot Rank

From the contingency analyses conducted in this study the dependence between variables can be derived by the levels of significance listed in Table VII.

TABLE VII

LEVEL OF SIGNIFICANCE LIST BETWEEN VARIABLES

	Flying Time in Model	Aircraft Type	Flying Time	Phase of Operation	Mission Type	Pilot Rank
Phase of Operation	.0184	.0000	.5449		.0000	
Aircraft Damage	.4175	.0002	.0629	.0000		
Pilot Rank	.0001	.0000	.0000	.0297		
Pilot Injury*	.6836	.0302	.0509	.0000	.0597	.0651

$\boxed{}$ = statistically significant variables

*Variables which were proved significant at the level of .1 were selected for the discriminant function

The prime variable, pilot's injury, was found to be dependent on the following with less than .1 significance: aircraft type, flying time, phase of operation, type of mission, and pilot rank. A level of significance less than .1 implies some relationship between pilot's injury and the above mentioned variables. So, the function for discriminating between the fatality and the non-fatality of the pilot involved in accidents included these variables.

However, as the variables, except flying time, are not measured on the metric scale it was hard to include them in the discriminant function. Therefore, all nominal scales were converted to metric scales by assigning them a number based on the degrees of each category's severity. Those were determined by this function: the severity of each category = the number of pilot deaths in that accident category divided by total number of accidents in that category multiplied by 100. For example, the severity of shooting missions is: 27 pilots deaths divided by 44 accidents = .6136; multiply by 100 to obtain the severity value of 61.36. Other examples:

Takeoff phase:	16 deaths divided by 60 accidents X 100 = 26.67
Students:	5 deaths divided by 23 accidents X 100 = 21.74
F-86:	17 deaths divided by 129 accidents X 100 = 44.19

This made it possible for all the variables mentioned above to be included in the discriminant function. The values for each category are as in Table VIII.

TABLE VIII

VALUES REPRESENTING NOMINAL VARIABLES

Variable	Category	Value	Variable	Category	Value
Mission	1. Shooting	61.36	Phase	1. Takeoff	26.67
	2. Intercept	31.58		2. Inflight	51.75
	3. Acrobatic	20.34		3. Approach	60.61
	4. Liaison	26.67		4. Landing	19.73
	5. Air Combat Maneuvering	44.83			
	6. Navigation	30.00	Rank	1. Student	21.74
	7. Reconnaissance	33.33		2. 2nd Lt	41.27
	8. Test Flight	44.44		3. 1st Lt	43.59
	9. Formation	44.44		4. Captain	34.94
	10. Close Air Support	66.67		5. Major	54.55
	11. Instrument	61.90		6. Lt Col	26.67
	12. Courier	30.00		7. Colonel	50.00
	13. Search	60.00			
			Type	1. F-4	66.67
				2. F-5	76.19
				3. F-86	44.19
				4. F-51	34.48
				5. T-33	45.16
				6. T-37	100.00
				7. T-28	33.33
				8. T-6	19.44
				9. C-Type	24.24
				10. H-Type	26.67
				11. Utility	42.86

So five variables, flying time of pilot, the mission type, the stage of operation, the rank, and the aircraft type have been selected for the discriminant analysis. Of them, the first represents the proficiency of the pilot and the others and for the relative riskiness of operation in each category. In selecting the variables, there is no multicolinearity between the variables. This is shown in Table IX.

TABLE IX

WITHIN GROUPS CORRELATION MATRIX

Variables	A	B	C	D	E
A	1.00000				
B	-.11975	1.00000			
C	-.14937	.32626	1.00000		
D	.10055	.14424	.12938	1.00000	
E	-.08673	.26294	.19353	.17495	1.00000

A: Total Flying Time
B: Type of Mission
C: Phase of Operation
D: Pilot Rank
E: Type of Aircraft

As there was only one accident of a T-37, much more data will be needed to confirm that the severity of T-37's is 100%. However, in this study the normal distributions are assumed.

Discriminant Analysis Results

A summary table for the stepwise discriminant analysis based on the maximum Rao's V, a generalized distance measure (Ref 8:448) criterion is provided in Table X. The standardized form is used because

> "each coefficient represents the relative contribution of its associated variable to that function. The sign merely denotes whether the variable is making a positive or negative contribution." (Ref 8:443)

TABLE X

STANDARDIZED DISCRIMINANT FUNCTION COEFFICIENT

Variables	Pilot's Injury Function Standardized Coefficients
Total Flying Time	-.53240
Severity of Mission Type	-.50463
Severity of Phase of Operation	-.32068
Severity of Pilot Rank	-.26648
Severity of Aircraft Type	-.34808

The implications of these results are very important. The total flying time variable shows the highest discriminating power among the five variables. Mission type indicates a higher discriminating power than the other three variables.

These results mean that the more flying time the pilot has, the greater is the probability of the pilot losing his life. And with less definiteness, it might be said that the more dangerous the mission that is involved in the accident, the greater the likelihood there exists of the pilot losing his life; a similar relationship exists for the mission type. Also, the more flying time the pilot has, the more likely it is for him to be involved in a fatal accident.

TABLE XI

DISCRIMINANT ANALYSIS SUMMARY (N = 179)

Variables	Partial F	Wilk's Lambda	Signifi-cance	Change in Rao's V	Signifi-cance
A	14.12820	.92608	.000	14.12820	.000
B	7.57166	.88788	.000	8.22249	.004
C	2.80079	.85125	.000	3.29392	.070
D	4.63946	.86495	.000	5.28503	.022
E	1.75965	.84268	.000	2.11493	.146

The formulas for classifications score were determined by classification function coefficients as follows:

The function for the fatal pilot group is:

.10921 (mission type) + .10684 (phase of operation)

+.53107 (pilot rank) + .13923 (aircraft type)

+.00199 (flying time) - 21.278 = classification score

The function for non-fatal pilot group is:

$$.08169 \text{ (mission type)} + .08844 \text{ (phase of operation)}$$
$$+ .50320 \text{ (pilot rank)} + .11885 \text{ (aircraft type)}$$
$$+ .00151 \text{ (flying time)} - 16.619 \qquad = \text{classification score}$$

The discriminant power of the five variables can be better visualized by referring to the classification results in Table XII (Ref 8:457). This Table shows the percentage of accidents correctly classified into each group.

TABLE XII

CLASSIFICATION RESULTS

		No of Cases	Predicted Group	
			Fatal Group	Non-fatal Group
Actual Group	Fatal Group	83	69.9%	30.1%
	Non-fatal Group	96	32.3%	67.7%

68.7% of known causes correctly classified $x^2 = 25.078$ significance = .000

Most important is the fact that 67.7% of the actual non-fatal group were correctly predicted and 69.9% of the actual fatal group were correctly predicted. From that table, the probability of misclassification error

is 31.3%. The misclassification error includes both α risk for predicting the actual non-fatal as fatal and β risk for predicting the actual fatal group as non-fatal.

V. CONCLUSIONS AND RECOMMENDATIONS

This study was conducted to evaluate accidents in ROKAF. A total population of 312 major accidents which occurred from 1955 through 1977 were analyzed. The quantitative level of risk was evaluated by "accident rate" and the decreasing rate according to the increase of cumulative flying time in ROKAF was estimated by regression analysis. The qualitative level of risk was indicated in terms of the fatality of accidents, and the qualitative variables and flying time variable were selected in order to predict the pilot's death from accidents. Based on the results of the study, the conclusions arrived at and recommendations made are presented below.

Conclusion 1

In ROKAF, 66.4% of aircraft accidents occurring from 1955 to 1977 were caused by pilot's error.

Recommendation

The most effective way to decrease the accidents is through approaching pilot error accidents. Although pilots are constantly confronted with a seemingly endless amount of material and requirements emphasizing flying safety, the results of this study suggest that the emphasis on pilot safety is necessary, should be continued, and maybe strengthened.

Conclusion 2

Of the total accidents, 45.8% occurred when the pilot's flying time was under 1000 hours, and 67.6% occurred when the pilot's time in model was under 500 hours. The pilot error accident rate decreases in an inverse proportion to the ROKAF's cumulative flying time. That means that the more flying time experience the ROKAF has, the lower is the pilot error accidents per 100,000 flying hours.

Recommendation

By decreasing the accident rate and saving pilots' lives, improving pilots' training will help the ROKAF meet the increasing burden of flying cost. "A stitch in time saves nine" applies in this case.

Conclusion 3

The result of the contingency table between the pilot's injury and the total flying time showed a close relationship between the two variables. This result is consistent with the belief in the ROKAF that the more flying time experience a pilot has, the less chance he has of being involved in accidents, but the greater risk he takes of losing his life in case of an accident.

Recommendation

The program or procedure designed to reduce the occurrence of accidents and to increase the safety of pilots should be prepared separately. The policy for the lower flying time experienced pilots ought

70

to put an emphasis on decreasing the occurrence of accidents. On the other hand, the policy for higher flying time experienced pilots necessitates its emphasis on increasing safety for pilots.

Conclusion 4

The decreasing order of discriminating variables with respect to fatalities in an accident is that of operational phase, aircraft type, mission type, and rank. Among the various phases, accidents during approach result in more pilot fatalities, followed by inflight, takeoff, then landing. However, accidents are most likely to occur during the inflight phase. Following that, the landing phase, takeoff phase and approach phase are in a decreasing order of accident potentiality.

Recommendation

For the safety of flight (i.e., reduce fatalities in aircraft accidents), the ROKAF should pay close attention to phases of operation, especially the approach phase which has the highest discriminating standardized value. However, to decrease the accident rate, it must pay attention to the inflight phase.

Suggestions for Further Research

It is desirable that more analysis of this type be done on the accident data presently available. For example, as this study was designed to give an indication of where to concentrate future safety efforts and to

show how successful past efforts have been, further research is needed to find out why pilots make errors and how such errors can be eliminated. In the process of researching this study it was discovered that a considerable amount of accident data was available on ROKAF accidents, but very little had been done with that data in the way of statistical analysis.

It is recommended that more of this type analysis be done. As there were many results of analysis not used for this study, but thought to be useful for another study, these results are included in Appendix D.

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APPENDIX A

Table of Symbols and Definitions for Aircraft

Type	Model	Acquisition	Description
F-4	E D	Oct 77 Aug 68	Two engine, all weather attack fighter capable of performing air superiority close air support, interdiction mission.
F-5	A B E F	Apr 65 Apr 65 Sep 74 Sep 74	Two engine dual mission for fighter and training. Basic interception weapon. Wide range of combat and photographic reconnaissance.
F-86	F D	Jun 55 Oct 58	Single engine, low wing fighter. All weather interceptor.
F-51	D	51	Two seat, one engine propeller fighter.
T-33	A	Aug 55	Standard jet trainer, good navigational equipment.
T-37	A	Nov 76	Jet trainer. Performs military surveillance, low level attack duty. Side-by-side seats.
T-28	A	Dec 60	Designed for replacement of T-6 trainer. Two seat basic trainer.
T-6	A	Feb 54	Economical standard trainer.
C-46	D	Apr 55	Two reciprocating engines, troop and cargo carrying, transports 4 crew members.
C-54	D	Jun 66	4 engine long range military transport.
C-123	K	Jan 74	Tactical transport, improved takeoff performance.

Type	Model	Acquisition	Description
C-118		May 70	4 engine turbo prop transport for VIP.
UH	1H B N	Oct 67 Oct 67 Jan 71	One and two jet engine passenger, cargo, transport, air reserve mission.
T-41	B	Jul 72	Student pilot trainer. Used in basic training before passing on to the T-37 jet primary trainer.
O-1	G/A	67	Light reconnaissance and observation aircraft.
O-2	A	Sep 74	Liaison and training mission

(Ref 5)

APPENDIX B

Equations for Regression Analysis of Empirical Data

1. The original function, $y = Ax^{B}$, was transformed to the following:

$$\log Y' = \log A + B \log x$$

2. As the accident rate is the average rate of each year, it is necessary to get the cumulative time midpoints as follows.

Time midpoints, first rough approximation:

$$X_j = \text{Cum } F_{j-1} + .5\, F_j$$

Cum F_{j-1}; Cum flying time until year j-1,

F_j; flying time in year j (Ref 6:92). (See Figure 17)

3. The residual, the difference between the actual and the estimated value (Y') for each case, may be represented by the expression

$$\text{Residuals} = \log Y - \log Y' = \text{Sres}$$

If we substitute y for log Y, y' for log Y', a for log A, x for log X(Ref 15:470), the following function can be written in the more familiar regression equation form; $y' = a + Bx$ $y = y' + \text{Sres}$. From that, the values of B and a come out

$$B = \left[\frac{\sum(x-\bar{x})(y-\bar{y})}{\sum(x-\bar{x})^2}\right] \qquad a = \bar{y} - B\bar{x} \quad \text{(Ref 15:323)}$$

4. Standard error of estimate (unbiased)

$$S = \left[\frac{\sum(y-y')^2}{n-2}\right]^{\frac{1}{2}} \qquad \text{(Ref 6:93)}$$

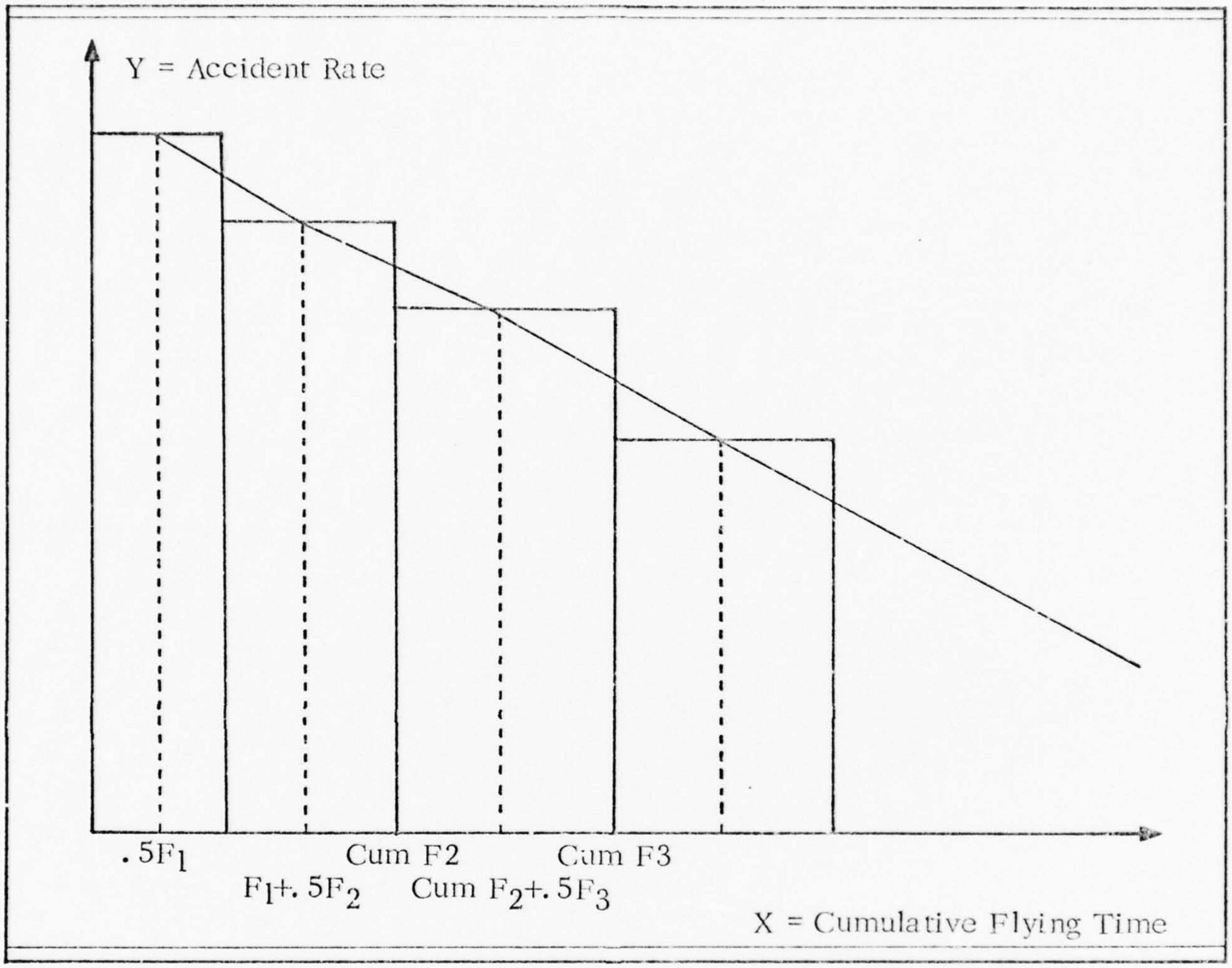

Figure 17. Hypothetical Relationship Between Accident Rate and Cumulative Flying Time.

5. The coefficient of determination (R^2) comes from its definition

$$Yxy^2 = \frac{\sum(y-\bar{y})^2 - \sum(y'-\bar{y}')^2}{\sum(y-\bar{y})^2} \qquad \text{(Ref 15:324)}$$

APPENDIX C

Analytical Techniques for Discriminant Analysis

There are three basic underlying assumptions of discriminant analysis. They are (1) that the two groups being investigated are discrete and identifiable, (2) that each observation in each group can be described by a set of measurements on several characteristics or variables, the 5 variables used for this study, and (3) that these several variables are assumed to have a multivariate normal distribution in each population and equal covariance matrices among populations. The first two assumptions are seen to be satisfied as discussed in Chapter III. The third assumption indicates the need for separate statistical tests to determine if the variables are multivariate normal and if the covariance matrices are equal. Since no satisfactory tests exist for testing populations to be multivariate normal, it is difficult to routinely test the normality assumption. Finally, the central limit theorem suggests that as the number of observations increases, the discriminant values for each group approaches a normal distribution (Ref 16:206).

The assumption of equality of covariance matrices (for example, equality of within group dispersions) appears to be more critical in biasing the results. The within group dispersion matrices for the two groups of data were computed and are shown in Appendix D. The pooled

within-groups dispersion matrix is also shown. The group dispersion matrices were tested for equality by the procedure given in Appendix D. After satisfying the assumptions preparatory to the actual analysis one can first test the equality of group means. The null hypothesis is:

$$\text{Ho:} \quad \bar{u}_1 = \bar{u}_2$$

where $\bar{u}_1 = (\bar{u}_{1,1}, \bar{u}_{1,2}, \bar{u}_{1,3}, \bar{u}_{1,4}, \bar{u}_{1,5})$

and $\bar{u}_2 = (\bar{u}_{2,1}, \bar{u}_{2,2}, \bar{u}_{2,3}, \bar{u}_{2,4}, \bar{u}_{2,5})$

The following steps are used by this analysis to test for the equality of group means:

Step (1) the means for each group are computed

$$\bar{x}_i = (\bar{x}_{i,1}, \bar{x}_{i,2}, \bar{x}_{i,3}, \bar{x}_{i,4}, \bar{x}_{i,5}) \quad i = 1, 2$$

Step (2) the differences in group means are computed

$$\bar{x}_1 - \bar{x}_2 = (\bar{x}_{1,1} - \bar{x}_{2,1}, \bar{x}_{1,2} - \bar{x}_{2,2}, \bar{x}_{1,3} - \bar{x}_{2,3}, \bar{x}_{1,4} - \bar{x}_{2,4}, \bar{x}_{1,5} - \bar{x}_{2,5})$$

Step (3) the matrices s^1 and s^2 are computed where an element of the s^1 is given by

$$S^i_{u,v} = \sum_{j=1}^{ni} (Xiju - \bar{x}i, u)(Xiju - \bar{x}i, v) \text{ and}$$

$i = 1, 2; \; u = 1, 2, 3, 4, 5; \; v = 1, 2, 3, 4, 5$

Step (4) the matrix A is computed

$A = S^1 + S^2$ where $(a^{j1}, a^{j2}, a^{j3}, a^{j4}, a^{j5})$ is the j^{th} row of A

Step (5) the Mahalanobis D^2 statistic is computed

$$D^2 = (n_1 + n_2 - 2) \sum_{i=1}^{m} \sum_{j=1}^{m} a^{ij} (\bar{x}_{1,i} - \bar{x}_{2,i})(\bar{x}_{1,j} - \bar{x}_{2,j})$$

Step (6) The F statistic is computed

$$\frac{n_1 n_2 (n_1 - n_2 - m - 1)}{m(n_1 - n_2)(n_1 - n_2 - 2)} \cdot D^2 \sim F^{m}_{n_1 - n_2 - m - 1}$$

where n_1 and n_2 are the respective sizes of the two groups and m is the number of variables.

The null hypothesis can be rejected when the value of the test statistic is greater than the tabled value of F for the desired level of significance.

The construction of the discriminant function is predicated upon minimizing the effects of misclassification (Table XIII) and assigning subjects to the group to which they have the greatest resemblance. The effects of misclassification depend upon the a the a priori knowledge of group membership and the costs or penalties of misclassification.

TABLE XIII

α Risks and β Risks in Classification

		Decision	
		Fatal Pilot Group	Non-Fatal Pilot Group
Truth	Fatal Pilot Group	0	β Risk
	Non-fatal Pilot Group	α Risk	0

The spss programs assume no special a priori probability of belonging to either group; for example, the probability of belonging to either group (in the two-group case) is one-half. They also assume the costs of misclassification to be equal; for example, the cost of assigning an actual member of group number one to group number two is the same as assigning a member of group number two to group number one.

The measure of resemblance is determined by the several characteristics which describe each subject. By substituting the values of the characteristics into each group's probability density function, it is determined how closely the subject resembles the group as compared with the rest of the population. The spss programs yield the coefficients and constants for the linear classification function for each group in the total population.

In order to determine what effect the chosen variables had on pilot's injury, it was desirable to measure the association among the variables. The association measure employed was the product-moment correlation coefficient. The correlation computations and correlation matrix for the entire data set is given in Appendix D.

For the association measure among data units, most investigators use metric measures when the data units are described by interval variables. Metric measures must satisfy certain properties. If E is a

given measurement space and x, y, and z are points in E, then an association function D is a metric measure if, and only if, it satisfies the following conditions:

For the metric scale, the following characteristics are approved.

(1) $D(X,Y) = D$ if and only if $X = Y$

(2) $D(X,Y) \geq D$ for all X and Y in E

(3) $D(X,Y) = D(Y,X)$ for all X and Y in E

(4) $D(X,Y) \leq D(Y,Z) + D(Y,Z)$ for all X, Y and Z in E

where $D_{(X,Y)}$ = distance between X and Y

For the nominal scales, those cannot be approved.

As some variables from the contingency table are measured by nominal number, it is necessary to convert to metric measure associated with the aircraft accident risk. To each nominal number, the percentage of fatal accidents to total accidents was applied to convert to a metric measure.

FLYING TIME BY YEAR, AIRCRAFT TYPE

Year	F4	F5	F86	F51	T33	T27	T28	T6	Utility	C-Type	Heli-copter	Total
1955	0	0	0	33597	0	0	0	11265	6078	0	0	50940
1956	0	0	28694	27459	11695	0	0	13651	4654	4033	0	90186
1957	0	0	37413	18867	12403	0	0	12604	5046	4826	0	91195
1958	0	0	40162	0	13167	0	0	13428	3927	5663	0	76337
1959	0	0	34642	0	10101	0	0	14253	3626	5926	0	68548
1960	0	0	35694	0	11727	0	0	12245	2488	5887	769	68810
1961	0	0	40831	0	12579	0	13699	9901	2079	5848	1068	86005
1962	0	0	37879	0	12500	0	12481	5747	2758	4901	1046	77292
1963	0	0	47163	0	12500	0	13080	0	2419	5375	967	81504
1964	0	0	45985	0	12048	0	11842	0	2895	4878	999	78627
1965	0	0	33898	0	10989	0	11223	0	2509	4808	1904	65331
1966	0	0	32644	0	11617	0	10604	0	2514	6909	2357	66645
1967	0	14019	31641	0	11904	0	9985	0	3103	9009	2809	82470
1968	0	17051	33223	0	11957	0	9369	0	3300	12280	5045	92225
1969	810	2000	26601	0	10811	0	7568	0	2519	14196	2272	84777
1970	4684	19355	18072	0	12846	0	5334	0	4277	15127	3819	86514
1971	5050	23339	22320	0	15625	0	12275	0	5500	11870	1851	97830
1972	4310	24000	20833	0	12821	0	9550	0	7558	10255	3177	92604
1973	9118	15302	21304	0	12434	1518	8065	0	5135	7431	2729	83036
1974	11105	15725	24612	0	10878	3992	4825	0	4960	6151	2154	84406
1975	14561	25295	18225	0	11223	4132	5054	0	6705	6914	2114	94223
1976	9364	40386	16278	0	12100	10559	4392	0	7396	7774	2094	110342
1977	10261	52859	18507	0	9134	11435	3895	0	8362	9390	2889	126732
Total	69263	267331	666601	79923	263049	31636	156325	93094	99808	169450	40063	1936543

NUMBER OF ACCIDENTS BY AIRCRAFT TYPE BY YEAR

Year	F-4	F-5	F-86	F-51	T-33	T-37	T-28	T-6	Utility	C-Type	Heli-copter	Total
1955	0	0	3	17	0	0	0	6	7	0	0	33
1956	0	0	8	10	2	0	0	7	7	0	0	35
1957	0	0	9	2	0	0	0	6	4	0	0	21
1958	0	0	11	0	6	0	0	4	1	1	0	23
1959	0	0	8	0	3	0	0	8	0	2	0	21
1960	0	0	14	0	0	0	0	3	1	0	0	18
1961	0	0	14	0	2	0	1	1	1	2	0	21
1962	0	0	7	0	1	0	0	1	0	0	0	9
1963	0	0	8	0	2	0	0	0	2	1	0	13
1964	0	0	6	0	2	0	0	0	1	1	1	11
1965	0	0	4	0	2	0	0	0	2	1	0	9
1966	0	1	4	0	0	0	0	0	1	1	0	7
1967	0	3	6	0	1	0	0	0	0	1	1	12
1968	0	0	10	0	0	0	1	0	0	0	0	11
1969	0	3	0	0	4	0	1	0	0	1	2	11
1970	0	3	3	0	0	0	0	0	0	0	2	8
1971	1	0	4	0	0	0	1	0	1	1	0	8
1972	0	3	1	0	2	0	1	0	0	0	0	7
1973	1	1	2	0	1	0	1	0	1	0	1	8
1974	0	3	4	0	1	0	0	0	1	1	0	10
1975	0	2	2	0	0	0	0	0	3	1	0	8
1976	1	1	1	0	1	1	0	0	0	1	0	6
1977	0	1	0	0	1	0	0	0	0	0	0	2
Total	3	21	129	29	31	1	6	36	33	15	7	312

TOTAL ACCIDENT RATE BY YEAR, TYPE

Year	F-4	F-5	F-86	F-51	T-33	T-37	T-28	T-6	Utility	C-Type	Heli-copter
1955	0.0	0.0	0.0	50.6	0.0	0.0	0.0	53.3	115.2	0.0	0.0
1956	0.0	0.0	27.9	36.4	17.1	0.0	0.0	51.3	150.4	0.0	0.0
1957	0.0	0.0	24.1	10.6	0.0	0.0	0.0	47.6	79.3	0.0	0.0
1958	0.0	0.0	27.4	0.0	45.6	0.0	0.0	29.8	25.5	17.7	0.0
1959	0.0	0.0	23.1	0.0	29.7	0.0	0.0	56.1	0.0	33.7	0.0
1960	0.0	0.0	39.2	0.0	0.0	0.0	0.0	24.5	40.2	0.0	0.0
1961	0.0	0.0	34.3	0.0	15.9	0.0	7.3	10.1	48.1	34.2	0.0
1962	0.0	0.0	18.5	0.0	8.0	0.0	0.0	17.4	0.0	0.0	0.0
1963	0.0	0.0	17.0	0.0	16.0	0.0	0.0	0.0	82.7	18.6	0.0
1964	0.0	0.0	13.1	0.0	16.6	0.0	0.0	0.0	34.5	20.5	100.1
1965	0.0	0.0	11.8	0.0	18.2	0.0	0.0	0.0	79.7	20.8	0.0
1966	0.0	0.0	12.3	0.0	0.0	0.0	0.0	0.0	39.8	14.5	0.0
1967	0.0	21.4	19.0	0.0	8.4	0.0	0.0	0.0	0.0	11.1	35.6
1968	0.0	0.0	30.1	0.0	0.0	0.0	10.7	0.0	0.0	0.0	0.0
1969	0.0	15.0	0.0	0.0	37.0	0.0	13.2	0.0	0.0	7.0	88.0
1970	0.0	15.5	16.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.4
1971	19.8	0.0	17.9	0.0	0.0	0.0	8.1	0.0	18.2	8.4	0.0
1972	0.0	12.5	4.8	0.0	15.6	0.0	10.4	0.0	0.0	0.0	0.0
1973	11.0	6.5	9.4	0.0	8.0	0.0	12.4	0.0	19.5	0.0	36.6
1974	0.0	19.1	16.3	0.0	9.2	0.0	0.0	0.0	20.2	16.3	0.0
1975	0.0	7.9	11.0	0.0	0.0	0.0	0.0	0.0	44.7	14.5	0.0
1976	10.7	2.5	6.1	0.0	8.3	9.5	0.0	0.0	0.0	12.9	0.0
1977	0.0	1.9	0.0	0.0	10.9	0.0	0.0	0.0	0.0	0.0	0.0

NUMBER OF PILOT ERROR ACCIDENTS BY YEAR, TYPE

Year	F-4	F-5	F-86	F-51	T-33	T-37	T-28	T-6	Utility	C-Type	Heli-copter	Total
1955	0	0	2	14	0	0	0	5	7	0	0	28
1956	0	0	5	10	1	0	0	3	5	0	0	25
1957	0	0	7	2	0	0	0	5	4	0	0	18
1958	0	0	5	0	6	0	0	1	0	0	0	12
1959	0	0	5	0	1	0	0	5	0	0	0	11
1960	0	0	6	0	0	0	0	2	1	0	0	9
1961	0	0	5	0	2	0	1	1	1	0	0	10
1962	0	0	7	0	1	0	0	1	0	0	0	9
1963	0	0	3	0	2	0	0	0	2	1	0	8
1964	0	0	6	0	1	0	0	0	1	0	0	8
1965	0	0	3	0	0	0	0	0	2	1	0	6
1966	0	1	4	0	0	0	0	0	1	0	0	6
1967	0	2	3	0	1	0	0	0	0	0	1	7
1968	0	0	6	0	0	0	1	0	0	0	0	7
1969	0	2	0	0	4	0	0	0	0	1	0	7
1970	0	3	2	0	0	0	0	0	0	0	1	6
1971	1	0	2	0	0	0	1	0	0	1	0	5
1972	0	2	1	0	1	0	1	0	0	0	0	5
1973	1	0	1	0	0	0	1	0	0	0	1	4
1974	0	3	2	0	1	0	0	0	1	1	0	8
1975	0	2	1	0	0	0	0	0	2	1	0	6
1976	1	0	0	0	0	0	0	0	0	0	0	1
1977	0	1	0	0	0	0	0	0	0	0	0	1
Total	3	16	76	26	21	0	5	23	27	6	3	207

NUMBER OF MATERIAL FAILURE ACCIDENTS BY YEAR, TYPE

Year	F-4	F-5	F-86	F-51	T-33	T-27	T-28	T-6	Utility	C-Type	Heli-copter	Total
1955	0	0	1	3	0	0	0	1	0	0	0	5
1956	0	0	2	0	1	0	0	2	2	0	0	7
1957	0	0	2	0	0	0	0	1	0	0	0	3
1958	0	0	5	0	0	0	0	1	1	0	0	7
1959	0	0	1	0	1	0	0	2	0	1	0	5
1960	0	0	5	0	0	0	0	1	0	0	0	6
1961	0	0	9	0	0	0	0	0	0	2	0	11
1962	0	0	0	0	0	0	0	0	0	0	0	0
1963	0	0	5	0	0	0	0	0	0	0	0	5
1964	0	0	0	0	1	0	0	0	0	1	1	3
1965	0	0	1	0	2	0	0	0	0	0	0	3
1966	0	0	0	0	0	0	0	0	0	1	0	1
1967	0	1	2	0	0	0	0	0	0	0	0	3
1968	0	0	3	0	0	0	0	0	0	0	0	3
1969	0	1	0	0	0	0	1	0	0	0	2	4
1970	0	0	1	0	0	0	0	0	0	0	1	2
1971	0	0	2	0	0	0	0	0	1	0	0	3
1972	0	1	0	0	1	0	0	0	0	0	0	2
1973	0	1	1	0	0	0	0	0	1	0	0	3
1974	0	0	0	0	0	0	0	0	0	0	0	0
1975	0	0	1	0	0	0	0	0	1	0	0	2
1976	0	1	1	0	1	1	0	0	0	0	0	4
1977	0	0	0	0	1	0	0	0	0	0	0	1
Total	0	5	42	3	8	1	1	8	6	5	4	83

NUMBER OF MAINTENANCE ERROR ACCIDENTS BY YEAR, TYPE

Year	F-4	F-5	F-86	F-51	T-33	T-27	T-28	T-6	Utility	C-Type	Heli-copter	Total
1955	0	0	0	0	0	0	0	0	0	0	0	0
1956	0	0	1	0	0	0	0	2	0	0	0	3
1957	0	0	0	0	0	0	0	0	0	0	0	0
1958	0	0	0	0	0	0	0	0	0	1	0	1
1959	0	0	2	0	0	0	0	0	0	0	0	2
1960	0	0	0	0	0	0	0	0	0	0	0	0
1961	0	0	0	0	0	0	0	0	0	0	0	0
1962	0	0	0	0	0	0	0	0	0	0	0	0
1963	0	0	0	0	0	0	0	0	0	0	0	0
1964	0	0	0	0	0	0	0	0	0	0	0	0
1965	0	0	0	0	0	0	0	0	0	0	0	0
1966	0	0	0	0	0	0	0	0	0	0	0	0
1967	0	0	0	0	0	0	0	0	0	0	0	0
1968	0	0	1	0	0	0	0	0	0	0	0	1
1969	0	0	0	0	0	0	0	0	0	0	0	0
1970	0	0	0	0	0	0	0	0	0	0	0	0
1971	0	0	0	0	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	0	0	0
1974	0	0	1	0	0	0	0	0	0	0	0	1
1975	0	0	0	0	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	5	0	0	0	0	2	0	1	0	8

NUMBER OF UNDETERMINED ACCIDENTS BY YEAR, TYPE

Year	F-4	F-5	F-86	F-51	T-33	T-37	T-28	T-6	Utility	C-Type	Heli-copter	Total
1955	0	0	0	0	0	0	0	0	0	0	0	0
1956	0	0	0	0	0	0	0	0	0	0	0	0
1957	0	0	0	0	0	0	0	0	0	0	0	0
1958	0	0	1	0	0	0	0	2	0	0	0	3
1959	0	0	1	0	1	0	0	1	0	1	0	3
1960	0	0	3	0	0	0	0	0	0	0	0	3
1961	0	0	0	0	0	0	0	0	0	0	0	0
1962	0	0	0	0	0	0	0	0	0	0	0	0
1963	0	0	0	0	0	0	0	0	0	0	0	0
1964	0	0	0	0	0	0	0	0	0	0	0	0
1965	0	0	0	0	0	0	0	0	0	0	0	0
1966	0	0	0	0	0	0	0	0	0	0	0	0
1967	0	0	1	0	0	0	0	0	0	1	0	2
1968	0	0	0	0	0	0	0	0	0	0	0	0
1969	0	0	0	0	0	0	0	0	0	0	0	0
1970	0	0	0	0	0	0	0	0	0	0	0	0
1971	0	0	0	0	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	0	0	0
1974	0	0	1	0	0	0	0	0	0	0	0	1
1975	0	0	0	0	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0	0	1	0	1
1977	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	6	0	1	0	0	3	0	3	0	13

TOTAL ACCIDENT RATE BY YEAR, CAUSE

Year	Pilot	Material	Maintenance	Undetermined	Total
1955	55.0	9.8	0.0	0.0	64.8
1956	27.7	7.8	3.3	0.0	38.8
1957	19.7	3.3	0.0	0.0	23.0
1958	15.7	9.2	1.3	3.9	30.1
1959	18.0	7.3	2.9	4.4	30.6
1960	13.1	8.7	0.0	4.4	26.2
1961	11.6	12.8	0.0	0.0	24.4
1962	11.6	0.0	0.0	0.0	11.6
1963	9.8	6.1	0.0	0.0	16.0
1964	10.2	3.8	0.0	0.0	14.0
1965	9.2	4.6	0.0	0.0	13.8
1966	9.0	1.5	0.0	0.0	10.5
1967	8.5	3.6	0.0	2.4	14.6
1968	7.6	3.3	1.1	0.0	11.9
1969	8.3	4.7	0.0	0.0	13.0
1970	6.9	2.3	0.0	0.0	9.2
1971	5.1	3.1	0.0	0.0	8.2
1972	5.4	2.2	0.0	0.0	7.6
1973	4.8	3.6	0.0	0.0	8.4
1974	9.5	0.0	1.2	1.2	11.8
1975	6.4	2.1	0.0	0.0	8.5
1976	.9	3.6	0.0	.9	5.4
1977	.8	.8	0.0	0.0	1.6

NUMBER OF TAKEOFF ACCIDENTS BY YEAR, TYPE

Year	F-4	F-5	F-86	F-51	T-33	T-37	T-28	T-6	Utility	C-type	Heli-copter	Total
1955	0	0	0	3	0	0	0	0	1	0	0	4
1956	0	0	2	2	0	0	0	0	1	0	0	5
1957	0	0	2	1	0	0	0	1	4	0	0	8
1958	0	0	1	0	3	0	0	0	0	0	0	4
1959	0	0	1	0	0	0	0	3	0	1	0	5
1960	0	0	1	0	0	0	0	0	0	0	0	1
1961	0	0	1	0	2	0	0	0	1	1	0	5
1962	0	0	2	0	0	0	0	0	0	0	0	2
1963	0	0	3	0	0	0	0	0	0	0	0	3
1964	0	0	1	0	0	0	0	0	0	1	0	2
1965	0	0	0	0	2	0	0	0	1	0	0	3
1966	0	0	0	0	0	0	0	0	1	0	0	1
1967	0	1	1	0	0	0	0	0	0	1	0	3
1968	0	0	2	0	0	0	0	0	0	0	0	2
1969	0	1	0	0	2	0	1	0	0	1	1	6
1970	0	0	0	0	0	0	0	0	0	0	2	2
1971	0	0	0	0	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	0	0	0
1974	0	1	0	0	0	0	0	0	0	0	0	1
1975	0	1	0	0	0	0	0	0	0	0	0	1
1976	0	0	1	0	0	1	0	0	0	0	0	2
1977	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	4	18	6	9	1	1	4	9	5	3	60

NUMBER OF INFLIGHT ACCIDENTS BY YEAR, TYPE

Year	F-4	F-5	F-86	F-51	T-33	T-37	T-28	T-6	Utiliy	C-type	Heli-copter	Total
1955	0	0	3	9	0	0	0	2	2	0	0	16
1956	0	0	5	3	2	0	0	4	6	0	0	21
1957	0	0	4	1	0	0	0	4	0	0	0	9
1958	0	0	7	0	1	0	0	2	1	0	0	11
1959	0	0	5	0	2	0	0	3	0	0	0	10
1960	0	0	8	0	0	0	0	0	0	0	0	8
1961	0	0	9	0	0	0	0	0	0	0	0	9
1962	0	0	3	0	1	0	0	1	0	0	0	5
1963	0	0	4	0	1	0	0	0	1	1	0	7
1964	0	0	4	0	1	0	0	0	0	0	1	6
1965	0	0	4	0	0	0	0	0	1	0	0	5
1966	0	1	2	0	0	0	0	0	0	0	0	3
1967	0	1	3	0	0	0	0	0	0	0	1	5
1968	0	0	6	0	0	0	1	0	0	0	0	7
1969	0	2	0	0	2	0	0	0	0	0	1	5
1970	0	2	2	0	0	0	0	0	0	0	0	4
1971	1	0	1	0	0	0	0	0	0	0	0	2
1972	0	3	1	0	2	0	0	0	0	0	0	6
1973	1	1	0	0	0	0	0	0	0	0	0	2
1974	0	0	1	0	0	0	0	0	0	0	0	1
1975	0	0	1	0	0	0	0	0	0	0	0	1
1976	0	0	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0
Total	2	10	73	13	12	0	1	16	11	1	3	143

NUMBER OF LANDING ACCIDENTS BY YEAR, TYPE

Year	F-4	F-5	F-86	F-51	T-33	T-37	T-28	T-6	Utility	C-type	Heli-copter	Total
1955	0	0	0	5	0	0	0	4	4	0	0	13
1956	0	0	0	3	0	0	0	3	0	0	0	6
1957	0	0	3	0	0	0	0	1	0	0	0	4
1958	0	0	3	0	2	0	0	2	0	1	0	8
1959	0	0	0	0	1	0	0	2	0	1	0	4
1960	0	0	2	0	0	0	0	3	1	0	0	6
1961	0	0	3	0	0	0	1	1	0	1	0	6
1962	0	0	1	0	0	0	0	0	0	0	0	1
1963	0	0	1	0	0	0	0	0	1	0	0	2
1964	0	0	0	0	0	0	0	0	1	0	0	1
1965	0	0	0	0	0	0	0	0	0	1	0	1
1966	0	0	2	0	0	0	0	0	0	1	0	3
1967	0	1	0	0	1	0	0	0	0	0	0	2
1968	0	0	0	0	0	0	0	0	0	0	0	0
1969	0	0	0	0	0	0	0	0	0	0	0	0
1970	0	1	0	0	0	0	0	0	0	0	0	1
1971	0	0	2	0	0	0	0	0	1	1	0	4
1972	0	0	0	0	0	0	1	0	0	0	0	1
1973	0	0	1	0	0	0	1	0	1	0	1	4
1974	0	0	2	0	0	0	0	0	1	0	0	3
1975	0	0	1	0	0	0	0	0	3	1	0	5
1976	0	1	0	0	0	0	0	0	0	0	0	1
1977	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	3	21	8	4	0	3	16	13	7	1	76

NUMBER OF APPROACH ACCIDENTS BY YEAR, TYPE

Year	F-4	F-5	F-86	F-51	T-33	T-37	T-28	T-6	Utility	C-type	Heli-copter	Total
1955	0	0	0	0	0	0	0	0	0	0	0	0
1956	0	0	1	2	0	0	0	0	0	0	0	3
1957	0	0	0	0	0	0	0	0	0	0	0	0
1958	0	0	0	0	0	0	0	0	0	0	0	0
1959	0	0	2	0	0	0	0	0	0	0	0	2
1960	0	0	3	0	0	0	0	0	0	0	0	3
1961	0	0	1	0	0	0	0	0	0	0	0	1
1962	0	0	1	0	0	0	0	0	0	0	0	1
1963	0	0	0	0	1	0	0	0	0	0	0	1
1964	0	0	1	0	1	0	0	0	0	0	0	2
1965	0	0	0	0	0	0	0	0	0	0	0	0
1966	0	0	0	0	0	0	0	0	0	0	0	0
1967	0	0	2	0	0	0	0	0	0	0	0	2
1968	0	0	2	0	0	0	0	0	0	0	0	2
1969	0	0	0	0	0	0	0	0	0	0	0	0
1970	0	0	1	0	0	0	0	0	0	0	0	1
1971	0	0	1	0	0	0	1	0	0	0	0	2
1972	0	0	0	0	0	0	0	0	0	0	0	0
1973	0	0	1	0	1	0	0	0	0	0	0	2
1974	0	2	1	0	1	0	0	0	0	1	0	5
1975	0	1	0	0	0	0	0	0	0	0	0	1
1976	1	0	0	0	1	0	0	0	0	1	0	3
1977	0	1	0	0	1	0	0	0	0	0	0	2
Total	1	4	17	2	6	0	1	0	0	2	0	33

NUMBER OF TAKEOFF ACCIDENTS BY YEAR, CAUSE

Year	Pilot	Material	Maintenance	Undetermined	Total
1955	4	0	0	0	4
1956	4	0	1	0	5
1957	8	0	0	0	8
1958	4	0	0	0	4
1959	2	2	0	1	5
1960	1	0	0	0	1
1961	3	2	0	0	5
1962	2	0	0	0	2
1963	0	3	0	0	3
1964	1	1	0	0	2
1965	1	2	0	0	3
1966	1	0	0	0	1
1967	1	1	0	1	3
1968	0	1	1	0	2
1969	3	3	0	0	6
1970	1	1	0	0	2
1971	0	0	0	0	0
1972	0	0	0	0	0
1973	0	0	0	0	0
1974	1	0	0	0	1
1975	1	0	0	0	1
1976	0	2	0	0	2
1977	0	0	0	0	0
Total	38	18	2	2	60

NUMBER OF INFLIGHT ACCIDENTS BY YEAR, CAUSE

Year	Pilot	Material	Mainte-nance	Undeter-mined	Total
1955	13	3	0	0	16
1956	14	6	1	0	21
1957	7	2	0	0	9
1958	3	5	0	3	11
1959	6	1	1	2	10
1960	2	3	0	3	8
1961	4	5	0	0	9
1962	5	0	0	0	5
1963	5	2	0	0	7
1964	4	2	0	0	6
1965	4	1	0	0	5
1966	3	0	0	0	3
1967	3	1	0	1	5
1968	5	2	0	0	7
1969	4	1	0	0	5
1970	3	1	0	0	4
1971	2	0	0	0	2
1972	4	2	0	0	6
1973	1	1	0	0	2
1974	0	0	0	1	1
1975	1	0	0	0	1
1976	0	0	0	0	0
1977	0	0	0	0	0
Total	93	38	2	10	143

AD-A069 786 AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OHIO SCH--ETC F/G 1/2
AN ANALYSIS OF THE REPUBLIC OF KOREA AIR FORCE'S AIRCRAFT ACCID--ETC(U)
MAR 79 S H SUN

UNCLASSIFIED AFIT/GSM/SM/78S-21 NL

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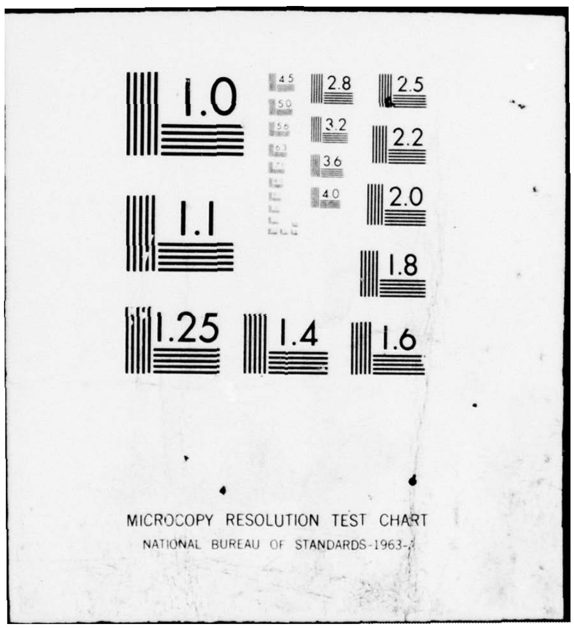
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-

NUMBER OF APPROACH ACCIDENTS BY YEAR, CAUSE

Year	Pilot	Material	Mainte-nance	Undeter-mined	Total
1955	0	0	0	0	0
1956	3	0	0	0	3
1957	0	0	0	0	0
1958	0	0	0	0	0
1959	1	0	1	0	2
1960	2	1	0	0	3
1961	0	1	0	0	1
1962	1	0	0	0	1
1963	1	0	0	0	1
1964	2	0	0	0	2
1965	0	0	0	0	0
1966	0	0	0	0	0
1967	1	1	0	0	2
1968	2	0	0	0	2
1969	0	0	0	0	0
1970	1	0	0	0	1
1971	1	1	0	0	2
1972	0	0	0	0	0
1973	0	1	0	0	2
1974	5	0	0	0	5
1975	1	0	0	0	1
1976	1	1	0	1	3
1977	1	1	0	0	2
Total	23	7	1	1	33

VITA

Suh Ho Sun was born Su Chun, Chung Nam, Korea, on September 13, 1939. He graduated from high school in Seoul in 1960 and attended the Korea Air Force Academy from which he graduated in 1964 with a Bachelor of Science degree and a Commission in the Korean Air Force. After completing pilot training he operationally flew the C-46 at Tae Gu AFB, the C-54 in Kim Hae AFB and Saigon in Vietnam in 1969; later in the VIP Squadron at Seoul AFB. In 1977 he was selected to attend the Air Force Institute of Technology at Wright-Patterson AFB, Ohio. He is married to Chung Ki Ok, Um Sung Chung Buk. They have two sons, Seung Bum and Seung Chan.

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This thesis was typed by Mrs. Eveanna Vaught.

NUMBER OF LANDING ACCIDENTS BY YEAR, CAUSE

Year	Pilot Error	Material Failure	Mainten ance Error	Undeter-mined	Total
1955	11	2	0	0	13
1956	4	1	1	0	6
1957	3	1	0	0	4
1958	5	2	1	0	8
1959	2	2	0	0	4
1960	4	2	0	0	6
1961	3	3	0	0	6
1962	1	0	0	0	1
1963	2	0	0	0	2
1964	1	0	0	0	1
1965	1	0	0	0	1
1966	2	1	0	0	3
1967	2	0	0	0	2
1968	0	0	0	0	0
1969	0	0	0	0	0
1970	1	0	0	0	1
1971	2	2	0	0	4
1972	1	0	0	0	1
1973	3	1	0	0	4
1974	2	0	1	0	3
1975	3	2	0	0	5
1976	0	1	0	0	1
1977	0	0	0	0	0
Total	53	20	3	0	76

NUMBER OF ACCIDENTS BY CAUSE, YEAR

Year	Pilot Error	Material Failure	Maintnenace Error	Undetermined	Total
1955	28	5	0	0	33
1956	25	7	3	0	35
1957	18	3	0	0	21
1958	12	7	1	3	23
1959	11	5	2	3	21
1960	9	6	0	3	18
1961	10	11	0	0	21
1962	9	0	0	0	9
1963	8	5	0	0	13
1964	8	3	0	0	11
1965	6	3	0	0	9
1966	6	1	0	0	7
1967	7	3	0	2	12
1968	7	3	1	0	11
1969	7	4	0	0	11
1970	6	2	0	0	8
1971	5	3	0	0	8
1972	5	2	0	0	7
1973	4	3	0	0	8
1974	8	0	1	1	10
1975	6	2	0	0	8
1976	1	4	0	1	6
1977	1	1	0	0	2
Total	207	83	8	13	312

AIRCRAFT TYPE VERSUS PHASE OF OPERATION

Count ROW PCT COL PCT TOT PCT	TAKEOFF FLIGHT 1	 2	APPROACH LANDING 3	 4	ROW TOTAL
1	0	2	1	0	3
	0	66.7	33.3	0	1.0
	0	1.4	3.0	0	
	0	.6	.3	0	
2	4	10	4	3	21
	19.0	47.6	19.0	14.3	6.8
	6.7	7.0	12.1	3.9	
	1.3	3.2	1.3	1.0	
3	18	73	17	21	129
	14.0	56.6	13.2	16.3	1.5
	30.0	51.4	51.5	27.6	
	5.8	23.5	5.5	6.8	
4	6	13	2	8	29
	20.7	44.8	5.9	27.6	9.3
	10.0	9.2	5.1	10.5	
	1.9	4.2	.6	2.6	
5	9	12	6	4	31
	29.0	38.7	19.4	12.9	10.0
	15.0	8.5	18.2	5.3	
	2.9	3.9	1.9	1.3	
6	1	0	0	0	1
	100.0	0	0	0	.3
	1.7	0	0	0	
	.3	0	0	0	
7	1	1	1	3	6
	16.7	16.7	16.7	50.0	1.9
	1.7	.7	3.0	3.9	
	.3	.3	.3	1.0	
8	4	16	0	16	36
	11.1	44.4	0	44.4	11.8
	6.7	11.3	0	21.1	
	1.3	5.1	0	5.1	
9	9	11	0	13	33
	27.3	33.3	0	39.4	10.6
	15.0	7.7	0	17.1	
	2.9	3.5	0	4.2	

AIRCRAFT TYPE VERSUS PHASE OF OPERATION
(Continued)

Count ROW PCT COL PCT TOT PCT	TAKEOFF FLIGHT 1	2	APPROACH LANDING 3	4	ROW TOTAL
10	5	1	2	7	15
	33.3	6.7	13.3	46.7	4.8
	8.3	.7	5.1	9.2	
	1.6	.3	.6	2.3	
11	3	3	0	1	7
	42.9	42.9	0	14.3	2.3
	5.0	2.1	0	1.3	
	1.0	1.0	0	.3	
COLUMN	60	142	33	76	311
TOTAL	19.3	45.7	10.6	24.4	100.0

RAW CHI SQUARE = 60.81079 WITH 30 DEGREES OF FREEDOM.
SIGNIFICANCE = .0007

AIRCRAFT DAMAGE VERSUS PHASE OF OPERATION

COUNT ROW PCT COL PCT TOT PCT	TAKEOFF 1	FLIGHT 2	APPROACH 3	LANDING 4	ROW TOTAL
1 MAJOR	29 30.9 48.3 9.3	27 28.7 18.9 8.7	3 3.2 9.1 1.0	35 37.2 46.1 11.2	94 30.1
2 DESTROY	31 14.2 51.7 9.9	116 53.2 81.1 37.2	30 13.8 90.9 9.6	41 18.8 53.9 13.1	218 69.9
COLUMN TOTAL	68 19.2	143 45.8	33 10.6	76 24.4	312 100.0

RAW CHI SQUARE = 34.13217 WITH 3 DEGREES OF FREEDOM. SIGNIFICANCE = .0000

AIRCRAFT TYPE VERSUS TYPE OF MISSION

COUNT ROW PCT COL PCT TOT PCT	COMBAT 1	TRAIN 2	SUPPORT 3	ROW TOTAL
1 FIGHTER	96 62.3 77.4 30.8	52 33.8 38.0 16.7	6 3.9 11.8 1.9	154 49.4
2 TRAINER	24 23.3 19.4 7.7	65 63.1 47.4 20.8	14 13.6 27.5 4.5	103 33.0
3 SUPPORT	4 7.3 3.2 1.3	20 36.4 14.6 6.4	31 58.4 60.8 9.9	55 17.6
COLUMN TOTAL	124 39.7	137 43.9	51 16.3	312 100.0

RAW CHI SQUARE - 123.30809 WITH 4 DEGREES OF FREEDOM. SIGNIFICANCE = .0000

TYPE OF MISSION VERSUS AIRCRAFT DAMAGE

COUNT / ROW PCT / COL PCT / TOT PCT		MAJOR 1	DESTROY 2	ROW TOTAL
COMBAT	1	28 22.6 29.8 9.0	96 77.4 44.0 30.8	124 39.7
TRAIN	2	49 35.8 52.1 15.7	88 64.2 40.4 28.2	137 43.9
SUPPORT	3	17 33.3 18.1 5.4	34 66.7 15.6 10.9	51 18.3
COLUMN TOTAL		95 30.1	218 69.9	312 100.0

RAW CHI SQUARE = 5.67325 WITH 2 DEGREE OF FREEDOM. SIGNIFICANCE = .0586

PILOT RANK VERSUS AIRCRAFT DAMAGE

COUNT / ROW PCT / COL PCT / TOT PCT		MAJOR 1	DESTROY 2	ROW TOTAL
UNSKILLED	1	28 32.2 29.8 9.0	59 67.8 27.1 18.9	87 27.9
SKILLED	2	60 29.1 63.8 19.2	146 70.9 67.0 46.8	206 68.0
FAMILIAR	3	6 31.6 6.4 1.9	13 68.4 6.0 4.2	19 6.1
COLUMN TOTAL		94 30.1	218 69.9	312 100.0

RAW CHI SQUARE = .29189 WITH 2 DEGREE OF FREEDOM. SIGNIFICANCE = .8642

PILOT INJURY VERSUS TYPE OF MISSION

COUNT / ROW PCT / COL PCT / TOT PCT		COMBAT 1	TRAIN 2	SUPPORT 3	ROW TOTAL
DEATH	1	56	48	17	121
		46.3	39.7	14.0	41.6
		49.6	37.2	34.7	
		19.2	16.5	5.8	
INJURY	2	20	22	6	48
		41.7	45.8	12.5	16.5
		17.7	17.1	12.2	
		6.9	7.6	2.1	
NONE	3	37	59	26	122
		30.3	48.4	21.3	41.9
		32.7	45.7	53.1	
		12.7	20.3	8.9	
COLUMN TOTAL		113	129	49	291
		38.8	44.3	16.8	100.0

RAW CHI SQUARE = 7.71001 WITH 4 DEGREES OF FREEDOM. SIGNIFICANCE = .1028

PILOT INJURY VERSUS AIRCRAFT DAMAGE

COUNT / ROW PCT / COL PCT / TOT PCT		DEATH 1	INJURY 2	NONE 3	ROW TOTAL
MAJOR	1	3	23	68	94
		3.2	24.5	72.3	30.1
		2.4	48.9	48.6	
		1.0	7.4	21.8	
DESTROY	2	122	24	72	218
		56.0	11.0	33.0	69.9
		97.6	51.1	51.4	
		39.1	7.7	23.1	
COLUMN TOTAL		125	47	149	312
		40.1	15.1	44.9	100.0

RAW CHI SQUARE = 76.17352 WITH 2 DEGREES OF FREEDOM. SIGNIFICANCE = .0000

PILOT INJURY VERSUS PHASE OF OPERATION

	COUNT ROW PCT COL PCT TOT PCT	TAKEOFF 1	FLIGHT 2	APPROACH 3	LANDING 4	ROW TOTAL
	1	16	74	20	15	125
DEATH		12.8	59.2	16.0	12.0	40.1
		26.7	51.7	60.6	19.7	
		5.1	23.7	5.4	4.8	
	2	11	19	2	15	47
INJURY		23.4	40.4	4.3	31.9	15.1
		18.3	13.3	5.1	19.7	
		3.5	6.1	.6	4.8	
	3	33	50	11	46	140
		23.6	35.7	7.9	32.9	44.9
NONE		55.0	35.0	33.3	60.5	
		10.6	16.0	3.5	14.7	
COLUMN		60	143	33	76	312
TOTAL		19.2	45.8	10.6	24.4	100.0

RAW CHI SQUARE = 32.10682 WITH 6 DEGREES OF FREEDOM. SIGNIFICANCE = .0000

PILOT INJURY VERSUS PILOT RANK

	COUNT ROW PCT COL PCT TOT PCT	1	2	3	4	5	6	7	ROW TOTAL
	1	5	26	34	29	24	4	2	124
DEATH		4.0	21.0	27.4	23.4	19.4	3.2	1.6	40.0
		21.7	41.3	43.6	34.9	54.5	26.7	50.0	
		1.6	8.4	11.0	9.4	7.7	1.3	.6	
	2	6	9	13	9	4	6	0	47
INJURY		12.8	18.1	27.7	19.1	8.5	12.8	0	15.2
		26.1	14.3	16.7	10.8	9.1	40.0	0	
		1.9	2.9	4.2	2.9	1.3	1.9	0	
	3	12	28	31	45	16	5	2	139
NONE		8.6	20.1	22.3	32.4	11.5	3.6	1.4	44.8
		52.2	44.4	39.7	54.2	36.4	33.3	50.0	
		3.9	9.0	10.0	14.5	5.2	1.6	.6	
COLUMN		23	63	78	83	44	15	4	310
TOTAL		7.4	20.3	25.2	26.8	14.2	4.8	1.3	100.0

RAW CHI SQUARE = 20.10841 WITH 12 DEGREES OF FREEDOM. SIGNIFICANCE = .0651

PILOT INJURY VERSUS TYPE OF MISSION

	COUNT ROW PCT COL PCT TOT PCT	1	2	3	4	5	6	7	8	9	10	11
DEATH	1	27	6	12	4	13	11	4	4	12	6	13
		22.3	5.0	9.9	3.3	10.7	9.1	3.3	3.3	9.9	5.0	10.7
		61.4	31.6	20.3	26.7	44.8	50.0	33.3	44.4	44.4	66.7	61.9
		9.3	2.1	4.1	1.4	4.5	3.8	1.4	1.4	4.1	2.1	4.5
INJURY	2	5	5	8	2	5	4	3	0	6	2	3
		10.4	10.8	18.8	4.2	10.4	8.3	6.3	0	12.5	7.2	6.3
		11.4	26.3	18.3	13.3	17.2	18.2	25.0	0	22.2	22.2	14.3
		1.7	1.7	3.1	.7	1.7	1.4	1.0	0	2.1	.7	1.0
NONE	3	12	8	38	9	11	7	5	5	9	1	5
		9.8	6.6	31.1	7.4	9.0	5.7	4.1	4.1	7.4	.8	4.1
		27.3	42.1	64.4	60.0	37.9	31.8	41.7	55.6	33.3	11.1	23.8
		4.1	2.7	13.1	3.1	3.8	2.4	1.7	1.7	3.1	.3	1.7
COLUMN TOTAL		44	19	59	15	29	22	12	9	27	9	21
		15.1	6.5		5.2	10.0	7.6	4.1	3.1	9.3	3.1	7.2

		12	13	ROW TOTAL
DEATH	1	6	3	121
		5.0	2.5	41.6
		30.0	60.0	
		2.1	1.0	
INJURY	2	4	0	48
		8.3	0	16.5
		20.0	0	
		1.4	0	
NONE	3	10	2	122
		8.2	8.6	41.9
		50.0	40.0	
		3.4	.7	
COLUMN TOTAL		20	5	291
		6.9	1.7	100.0

RAW CHI SQUARE = 33.84348 WITH 24 DEGREES OF FREEDOM.
SIGNIFICANCE = .0284

PILOT INJURY VERSUS TYPE OF AIRCRAFT

COUNT ROW PCT COL PCT TOT PCT	DEATH 1	INJURY 2	NONE 3	ROW TOTAL
1	2 66.7 1.6 .6	0 0 0 0	1 33.3 .7 .3	3 1.0
2	16 76.2 12.9 5.1	1 4.8 2.1 .3	4 19.0 2.9 1.3	21 6.8
3	57 44.2 46.0 18.3	20 15.5 42.6 6.4	52 40.3 37.1 15.7	129 41.5
4	10 34.5 8.1 3.2	4 13.8 8.5 1.3	15 51.7 10.7 4.8	29 9.3
5	14 45.2 11.3 4.5	2 6.5 4.3 .6	15 48.4 10.7 4.8	31 10.0
6	1 100.0 .8 .3	0 0 0 0	0 0 0 0	1 .3
7	2 33.3 1.6 .6	2 33.3 4.3 .6	2 33.3 1.4 .6	6 1.9
8	7 19.4 5.6 2.3	9 25.0 19.1 2.9	20 55.6 14.3 6.4	36 11.6
9	8 24.2 6.5 2.6	5 15.2 10.6 1.6	20 60.6 14.3 8.4	33 10.6

PILOT INJURY VERSUS TYPE OF AIRCRAFT
(Continued)

10	4	4	7	15
	26.7	26.7	46.7	4.8
	3.2	8.5	5.0	
	1.3	1.3	2.3	
11	3	0	4	7
	42.9	0	47.1	2.3
	2.4	0	2.9	
	1.0	0	1.3	
COLUMN	124	47	140	311
TOTAL	39.9	15.1	43.0	100.0

RAW CHI SQUARE = 33.43843 WITH 20 DEGREES OF FREEDOM.
SIGNIFICANCE = .0302

PILOT INJURY VERSUS TOTAL FLYING TIME

	COUNT ROW PCT COL PCT TOT PCT	Under 50 1	500 1000 2	1000 1500 3	1500 2000 4	2000 2500 5	2500 3000 6	3000 3500 7	3500 4000 8	Upper 4000 9	ROW TOTAL
DEATH	1	15 17.9 38.5 8.4	22 26.2 51.2 12.3	5 6.0 21.7 2.8	13 15.5 52.0 7.3	9 10.7 52.9 5.0	11 13.1 61.1 6.1	6 7.1 75.0 3.4	1 1.2 25.0 .6	2 2.4 100.0 1.1	84 46.9
INJURY	2	7 33.3 17.9 3.9	6 28.6 14.0 3.4	1 4.8 4.3 .6	0 0 0 0	3 14.3 17.6 1.7	3 14.3 18.7 1.7	0 0 0 0	1 4.8 25.0 .6	0 0 0 0	21 11.7
NONE	3	17 23.0 43.6 9.5	15 20.3 34.9 8.4	17 23.0 73.9 9.5	12 16.2 48.0 6.7	5 6.8 29.4 2.8	4 5.4 22.2 2.2	2 2.7 25.0 1.1	2 2.7 50.0 1.1	0 0 0 0	74 41.3
COLUMN TOTAL		39 21.8	43 24.0	23 12.8	25 14.0	17 9.5	18 10.1	8 4.5	4 2.2	2 1.1	179 100.0

RAW CHI SQUARE - 26.22967 WITH 16 DEGREES OF FREEDOM. SIGNIFICANCE = .0509

AIRCRAFT DAMAGE CLASSIFICATION VERSUS FLYING TIME

	Count ROW PCT COL PCT TOT PCT	1	2	3	4	5	6	7	8	9	ROW TOTAL
MAJOR	1	15 35.7 38.5 8.4	8 19.0 18.6 4.5	9 21.4 39.1 5.0	5 11.9 20.0 2.8	2 4.8 11.8 1.1	3 7.1 16.7 1.7	0 0 0 0	0 0 0 0	0 0 0 0	42 23.5
DESTROY	2	24 17.5 61.5 13.4	35 25.5 81.4 19.6	14 10.2 60.9 7.8	20 14.6 80.0 11.2	15 10.9 88.2 8.4	15 40.9 83.3 8.4	8 5.8 100.0 4.5	4 2.9 100.0 2.2	2 1.5 100.0 1.1	137 76.5
	COLUMN TOTAL	39 21.8	43 24.0	23 12.8	25 14.0	17 9.5	18 10.1	8 4.5	4 2.2	2 1.1	179 100.0

RAW CHI SQUARE = 14.81151 WITH 8 DEGREES OF FREEDOM. SIGNIFICANCE = .0629

APPENDIX D

Results From Discriminant Analysis

	Fatal Pilot Group	Nonfatal Pilot Group	Total
No. of Accidents	83	96	179
Means			
total flying time	1634.92771	1291.63542	1450.81564
mission	42.58578	38.99698	42.97950
phase	44.40783	37.77083	40.84832
rank	42.76241	39.38469	40.95089
type	48.12711	41.56667	44.60866
Standard Deviations			
total flying	997.37593	918.06905	968.28063
mission	14.46347	15.88933	15.79735
phase	14.90167	16.13363	15.88188
rank	8.37015	7.83170	8.23789
type	16.44339	12.33186	14.71347
Classification Function Coefficients			
Total flying time	.00199	.00151	
Mission	.10921	.08169	
Phase	.10584	.08844	
Rank	.53107	.50320	
Type	.13923	.11885	
Constant	- 21.278	-16.619	
Centroids of Groups	-.46208	-.39951	

Within Groups Covariance Matrix

	Total Time	Mission	Phase	Rank	Type
Total Time	913226.22489				
Mission	-1744.59792	232.42073			
Phase	-2223.18522	77.46895	242.58108		
Rank	776.96892	17.77970	16.29376	65.37703	
Type	-1192.06324	52.65706	43.35614	20.34624	206.88515

Total Covariance Matrix

	Total Time	Mission	Phase	Rank	Type
Total Time	937567.38717				
Mission	- 997.44790	249.56267			
Phase	-1640.90907	91.28917	252.23415		
Rank	1062.58140	24.93473	21.80847	67.86289	
Type	- 622.15277	71.42415	54.00139	25.77351	216.48610

Discriminant Function Coefficients

	Standardized	Unstandardized
Flying Time	-.53240	-.000550
Mission	-.50463	-.031944
Phase	-.32068	-.020192
Rank	-.26648	-.032348
Type	-.34808	-.023658
Constant		5.37545